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THE SOUTH ADAMS COUNTY WATER AND SANITATION DISTRICT'S SHALLOW ALLUVIAL WELLS ARE CONTAMINATED WITH A VARIETY OF VOLATILE AND NON-VOLATILE ORGANIC CHEMICALS. PREVIOUS STUDIES HAVE DETERMINED THAT GRANULAR ACTIVATED CARBON IS THE MOST FEASIBLE METHOD OF TREATMENT FOR REMOVAL OF THE ORGANIC CONTAMINANTS FROM THE DISTRICT'S DRINKING WATER SUPPLY. THE PURPOSE OF THIS STUDY IS TO PERFORM A DETAILED ANALYSIS OF THE WATER SYSTEM MODIFICATIONS AND THE GAC TREATMENT ALTERNATIVES WITH REGARD TO COST, CONSTRUCTABILITY, AND RELIABILITY IN MEETING WATER QUALITY GOALS. ALONG WITH RECOMMENDATIONS, DETAILED FINDINGS ARE PRESENTED ON:

1. WATER SUPPLY AND DEMAND
2. WATER QUALITY
3. WATER COLLECTION, PUMPING, AND DISTRIBUTION MODIFICATIONS
4. WATER TREATMENT FACILITIES
5. ADMINISTRATION AND SUPPORT FACILITIES.

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south adams county
water and sanitation district

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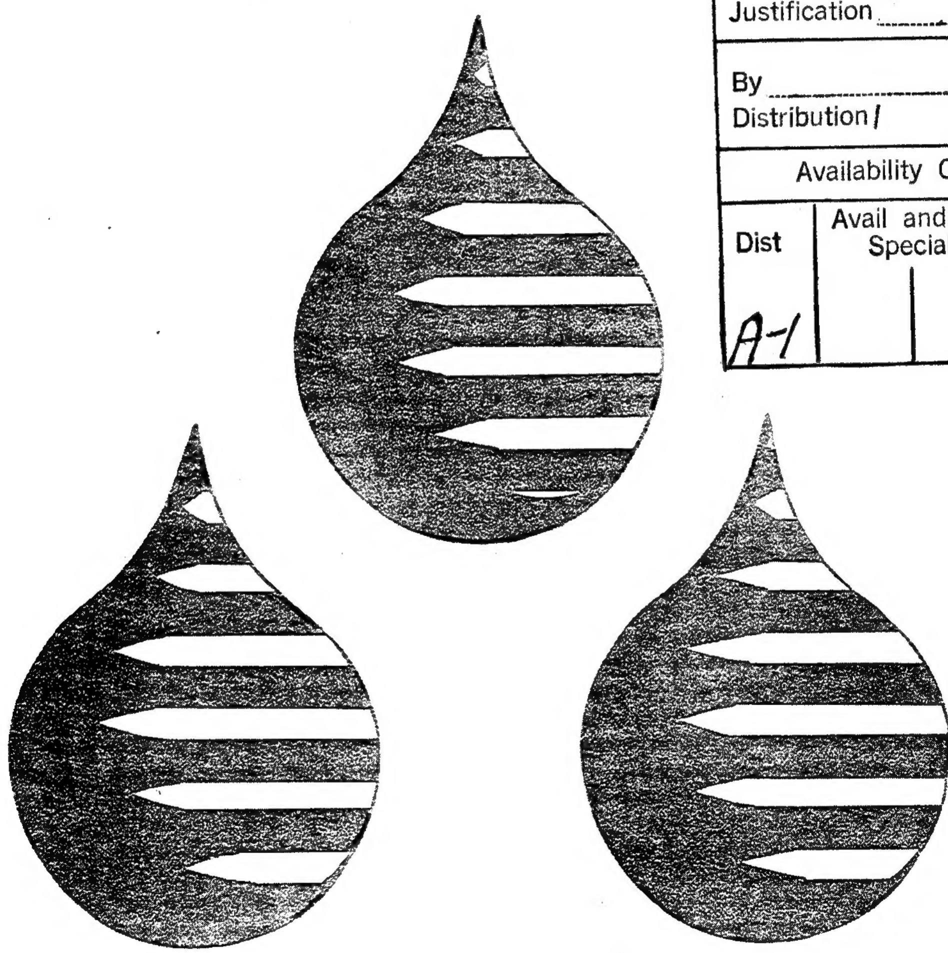

Black & Veatch
Engineers-Architects

86335R02
ORIGINAL

DETAILED ANALYSIS OF ALTERNATIVES
FOR ORGANIC CONTAMINANT REMOVAL

REVIEW DRAFT

OCT 08 1986

SOUTH ADAMS COUNTY
WATER AND SANITATION DISTRICT

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October 1986

SOUTH ADAMS COUNTY
WATER AND SANITATION DISTRICT

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CHAPTER 1

SUMMARY OF FINDINGS AND RECOMMENDATIONS

The South Adams County Water and Sanitation District's (SACWSD) shallow alluvial wells are contaminated with a variety of volatile and non-volatile organic chemicals. Previous studies have determined that granular activated carbon is the most feasible method of treatment for removal of the organic contaminants from the District's drinking water supply. The purpose of this study is to perform a detailed analysis of the water system modifications and the granular activated carbon treatment alternatives with regard to cost, constructability, and reliability in meeting water quality goals.

A. FINDINGS

The findings of this study, presented in detail in the body of this report, are summarized below.

1. WATER SUPPLY AND DEMAND.

- The service area boundary used as a basis for water supply and water demands is bounded on the north by 80th Avenue and by Sand Creek on the south.
- Full development in the service area will produce an approximate 12.0 mgd maximum day demand on the shallow wells.

2. WATER QUALITY.

- Existing contamination levels result in an average trichloroethylene (TCE) design concentration in the shallow well supply of 32 ug/l.

3. WATER TREATMENT FACILITY.

- A central water treatment facility is the most economical and feasible treatment approach.

- The optimum site location for the water treatment facility is on Rocky Mountain Arsenal property east of Quebec Street at 77th Avenue. Ten acres of land plus access to Quebec Street is required.

- Pressure type, downflow, fixed-bed contactors connected in parallel configuration were found to provide the lowest initial capital costs and maximize carbon utilization efficiencies.

- Backwashing capabilities for the fixed-bed contactors are required for proper and efficient use of the treatment facility.

- The projected activated carbon use rate at the water treatment facility is presently insufficient to justify on-site regeneration facilities.

- Chemical disinfection facilities are required at the treatment facility to permit disinfection of the contactors as well as the plant effluent water.

4. WATER COLLECTION, PUMPING, AND DISTRIBUTION MODIFICATIONS.

- Shallow wells at 77th Avenue and Pontiac Street, 77th Avenue and Quebec Street, and 64th Avenue and Quebec Street are the District's primary supply sources. Wells at 80th Avenue and Jasmine Street and at the District Offices are of lesser significance and were found to be economically unsuitable for connection to the treatment facility.

- The storage reservoirs at 77th Avenue and Pontiac Street, 64th Avenue and Quebec Street, and 56th Avenue and Niagara Street are the District's primary shallow well supply storage facilities. Storage reservoirs at the 80th Avenue and Jasmine Street and at the District Offices were found to be economically unsuitable for connecting to the treatment facility, but will continue to be used for deep well storage and distribution.

- The most technically and economically feasible system to collect flow from the three supply points, convey it to the water treatment facility, and then return it to the three storage sites was found to be as follows. Flow from the three well supply points is collected by lines which join near the entrance of the treatment facility. The water passes through the facility and then is conveyed through transmission lines back to the three storage sites under pressure supplied from the well supply pumps.

5. ADMINISTRATION AND SUPPORT FACILITIES.

- An administration building is needed to support treatment facility operations treatment facility.
- A central instrumentation and control system is required to monitor and control the District's collection, treatment, and distribution system.
- An on-site gas chromatograph/mass spectrophotometer is necessary for on-site organic contaminant testing.

B. RECOMMENDATIONS

The recommendations of this study, presented in detail in the body of this report, are summarized below.

1. WATER SUPPLY AND DEMAND.

- Well supply and treatment capacity should be 12.0 mgd to meet the fully developed maximum day demand of the service area.
- Construction of improvements to Wells No. 2 and No. 3 located at 77th Avenue and Pontiac Street should be completed prior to the 1987 high demand period.

2. WATER TREATMENT FACILITY.

- The capacity of the water treatment facility should be 12.0 mgd.
- The water treatment facility should be located on the site at 77th Avenue, east of Quebec Street. Ten acres of land plus permanent access should be acquired from the Rocky Mountain Arsenal for the facility.

- Pressure type downflow, fixed-bed contactors should be used for the facility.

- The contactors should be connected in a parallel configuration. The effluent from all of the carbon contactors is blended to achieve maximum carbon usage and to meet drinking water standards.

- Sixteen 10-foot diameter units should be provided for treatment. Two additional 10-foot diameter units should be provided for both fresh and exhausted carbon storage. Each contactor will contain 20,000 pounds of activated carbon.

- The contactors should be equipped with backwash capabilities.

- The District should utilize a contract carbon replacement service.

- Chemical disinfection facilities should be included in the project.

3. WATER COLLECTION AND TRANSMISSION SYSTEM MODIFICATIONS.

- The shallow wells at 77th Avenue and Pontiac Street, 77th Avenue and Quebec Street, and 64th Avenue and Quebec Street should be the only supply sources connected to the treatment facility. The shallow wells at 80th Avenue and Jasmine Street and at the District Offices should not be connected to the treatment facility collection system and should be disconnected from the adjacent storage reservoirs.

- The storage reservoirs at 77th Avenue and Pontiac Street, 64th Avenue and Quebec Street, and 56th Avenue and Niagara Street should be the only storage reservoir connected to the treatment facility. The storage reservoirs at 80th Avenue and Jasmine Street and at the District Offices should continue to operate in conjunction with the adjacent deep well supply system.

4. ADMINISTRATION AND SUPPORT FACILITIES.

- An administration building should be included in the project to support treatment facility operations.

- A central instrumentation and control system should be provided to monitor and control the complex supply, treatment, and transmission system.

- An on-site gas chromatograph/mass spectrophotometer should be provided to allow organic contaminant testing. The analytical instrument will be used to perform required regulatory monitoring as well as routine performance monitoring of the GAC units. This will allow the District to maintain close control on the effluent quality of the GAC units and will ensure maximum use of the carbon media.

5. OPINION OF PROBABLE COST.

- The opinion of probable costs for the recommended improvements is as follows:

Item	Cost ($)
Water Collection and Transmission System Modifications	1,469,000
Centralized Treatment Facility	6,157,000
Total Facilities Capital Costs	7,626,000
Design Engineering	610,000
Construction Engineering	381,000
Total Cost	8,617,000
Annual O&M Cost	546,000

6. SCHEDULE. Design and construction of the recommended improvements is estimated to be 16 months. Following regulatory review of this report, it is anticipated that design will begin in early December 1986. The schedule shown on Figure 7-3 indicates startup of the GAC treatment units approximately 12 months after the start of design.

CHAPTER 2
INTRODUCTION AND PURPOSE

A. BACKGROUND

The SACWSD is located north of the City of Denver and, in general, within an area bordered to the east by the Rocky Mountain Arsenal and to the west by the South Platte River. The SACWSD receives about 80 percent of its water from shallow alluvial wells of which the most productive are located within 1,500 feet of the western boundary of the Arsenal. The general direction of flow of the shallow alluvial ground water is from the Arsenal to the northwest toward the South Platte River.

As identified in numerous previous and ongoing studies, the District's shallow alluvial wells are contaminated with a variety of volatile and non-volatile organic chemicals. As a result of the contamination, the District has installed temporary, emergency treatment facilities to remove the contaminants and is currently pursuing permanent remedial improvements. A recently completed study, "Treatability/Feasibility Study for District Water Quality Improvement" by James M. Montgomery, Consulting Engineers, evaluated the most feasible treatment alternatives for accomplishing organic contaminant removal from the District's water supplies. The study evaluated air stripping, granular activated carbon adsorption, and air stripping in combination with activated carbon adsorption. For organic contaminant removal, granular activated carbon was recommended as the most feasible method of treatment.

The purpose of this study is to perform a detailed analysis of granular activated carbon treatment alternatives for organic contaminant removal with regard to cost, constructability, and reliability in meeting water quality goals. Also included in the study is an evaluation of the water collection and transmission modifications required to integrate the treatment facilities into the existing system.

B. SCOPE OF WORK

The SACWSD requested Statements of Qualifications on June 27, 1986 for a detailed analysis of alternatives to remove organic contaminants from the District's water supply. Following submittal of Statements of Qualifications by consultants and interviews, Black & Veatch was selected by the District for the project. The contract, dated August 27, 1986, outlines the following scope of work:

- Review existing data pertinent to this project, including information on the District's well supply, water quality, and quantity; layout and operations of the existing wells and transmission system; and previous reports and documents.
- Evaluate potential sites for the treatment facility, including planning for additional future facilities.
- Evaluate alternatives for modifications to supply wells and the collection-transmission system to provide flow into and out of treatment facility.
- Review data concerning performance of interim GAC treatment units.
- Evaluate alternative GAC treatment processes.
- Evaluate feasibility of District-owned and operated carbon reactivation facility.
- Recommend treatment facility layout and determine requirements for support facilities, including administration area, laboratory, and control and monitoring systems.
- Prepare an opinion of probable cost and projections of operation and maintenance expenses for the recommended facilities.
- Prepare a schedule for facility design and construction.
- Prepare final report.

CHAPTER 3

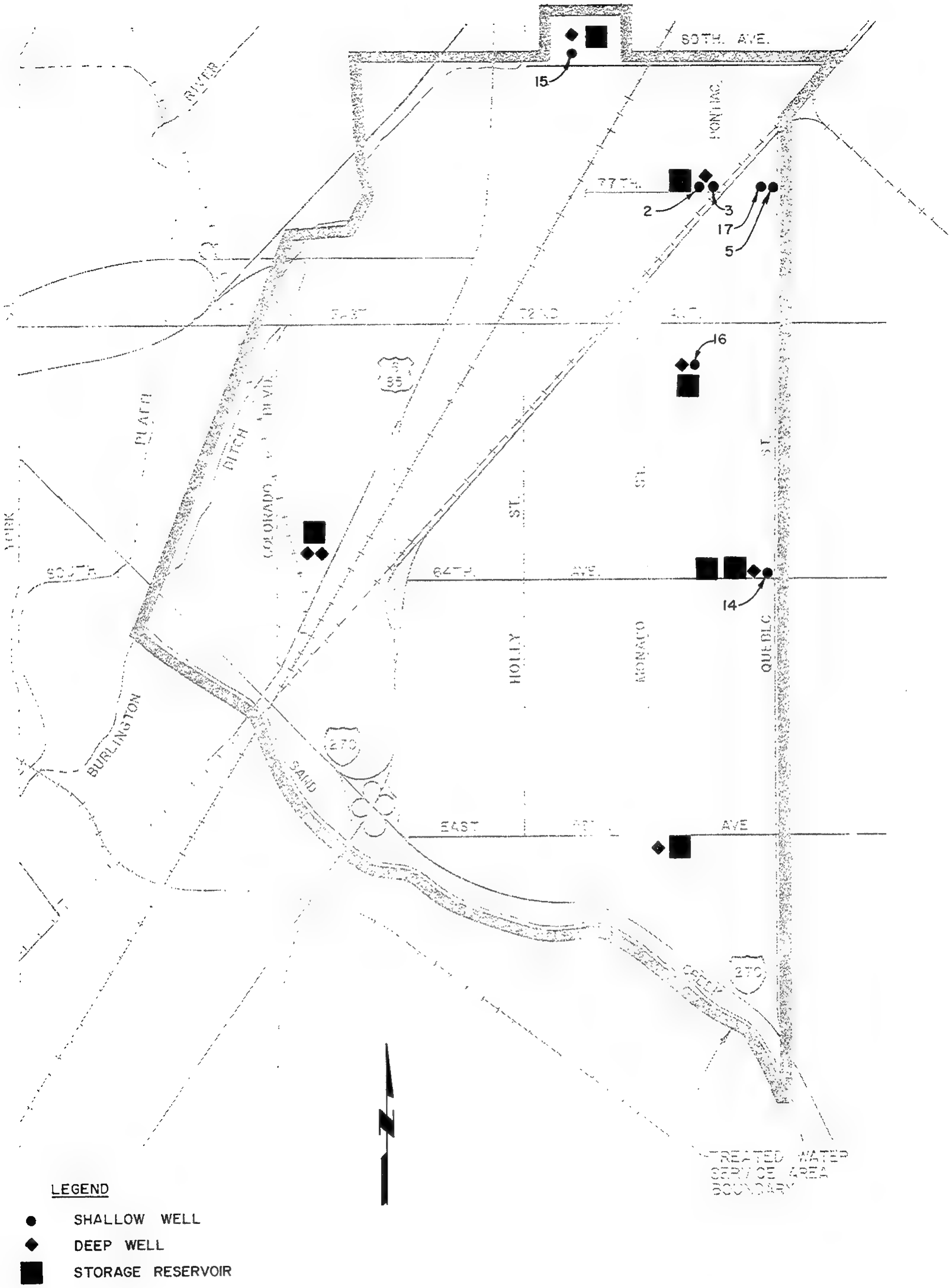
DESIGN CRITERIA

A. WATER SUPPLY AND DEMAND ESTIMATES

1. GENERAL BACKGROUND. The South Adams County Water and Sanitation District presently serves water which is withdrawn from wells in shallow and deep strata beneath the District. The supply consists of eight shallow wells and eight deep wells which provide water for the public distribution system. One shallow well and two deep wells supply water to the District's wastewater treatment plant but are not connected to the distribution system; they are, therefore, not of interest in the present study. The locations of the District's wells are shown on Figure 3-1.

As documented in this report, a determination has been made by the District's Board to provide treatment for the contaminated shallow well supply. The numerous testing programs, public meetings, feasibility studies, and the work completed for the current report, have led to a number of observations and conclusions regarding the well supply, the system demand, and the optimum design capacity for the proposed water treatment facility. A summary of observations, conclusions, and recommendations regarding the District's water supply and demand follows.

2. SHALLOW WELL SUPPLIES. The district's eight shallow wells are itemized in Table 3-1. Although the District extends from 50th Avenue on the south to 112th Avenue on the north, almost all of its customers are south of 80th Avenue. Seven of the eight shallow wells also lie on or south of 80th Avenue, which has been established as the boundary dividing the designated EPA Off-Post Remedial Investigation Feasibility Study area on the south from a non-designated area on the north. A determination has been made to provide treatment of all well supplies south of 80th Avenue. Therefore, Well No. 18, located at 84th Avenue and Quebec Street, will be presently left untreated and will be designated for service in the area north of 80th Avenue. Future expansion of demand in the District north of 80th Avenue will be met by construction of additional shallow wells in that area. If and when a need arises to provide treatment for the ground water



EXISTING WATER SUPPLY WELLS AND STORAGE RESERVOIRS

Figure 3-1

TABLE 3-1

TABULATION OF ALLUVIAL WELLS
IN THE SOUTH ADAMS COUNTY WATER AND SANITATION DISTRICT
(All Flows in Gallons per Minute)

Well Number	Location	Decreed Flow	Present Capacity	Maximum Withdrawal Rate[4]	Storage Reservoir Capacity (gal)
2	77th Ave. and Pontiac St.	996[2]	650	900	2,000,000
3	77th Ave. and Pontiac St.	2,092[2]	1,150	1,400	2,000,000
5	77th Ave. and Quebec St.	3,491[1]	1,300	2,200	None
14	64th Ave. and Quebec St.	987	800	750	2,300,000[3]
15	80th Ave. and Jasmine St.	310	100	60	300,000
16	District Office	799	300	270	600,000
17	77th Ave. and Quebec St.	3,491[1]	1,193	2,200	None
18	84th Ave. and Quebec St.	3,088[2]	1,400	1,500	2,000,000
	TOTAL	8,675 gpm	6,893 gpm	9,280 gpm	
		12.49 mgd	9.93 mgd	13.36 mgd	

[1] Well No. 17 is decreed as an Alternate Point of Diversion for Well No. 5. Therefore, Wells No. 5 and No. 17 have a joint decree of 3,491 gpm.

[2] Well No. 18 is an Alternate Point of Diversion for Well No. 2 and Well No. 3. Therefore, Wells No. 2, 3, and 18 have a joint decree of 3,088 gpm.

[3] Consists of one 2,000,000-gallon tank and one 300,000-gallon tank.

[4] Based upon a sustained usage over a 120-day period. Somewhat higher rates could occur for shorter time periods.

supplies north of 80th Avenue, that treatment most likely will be provided at one or more additional water treatment facilities constructed as the expansion proceeds.

The total present capacity of the shallow wells south of 80th Avenue is 7.9 mgd. This total can be increased to meet the maximum daily demand for the District's fully developed service area south of 80th Avenue if the pumps in the wells are replaced to optimize yields. The modifications to the pumps in the existing wells are required for a number of reasons, including the following:

- The commitment of Well No. 18 to the north area leaves an inadequate well supply south of 80th Avenue.
- The well pumps must all pump at higher heads, in order to overcome head losses in the water treatment plant and in the water collection and transmission system modifications.
- Wells No. 15 and 16 have relatively small capacities, making them less efficient to treat. An investigation is made herein to determine if greater efficiency can be achieved through the discontinuation of use of these wells and provision of their supplies from the other five wells.

3. SYSTEM DEMAND. At present, the District's eight shallow wells pump water into seven surface storage reservoirs, ranging in size from 300,000 gallons to 2,000,000 gallons. In most instances, the reservoirs are located adjacent to the supplying wells, but in some cases, the well supplies are pumped a considerable distance to storage. A booster pump station is located adjacent to each of the seven storage reservoirs. The booster pumps withdraw water from the reservoirs and pump directly into the pressurized distribution system. The distribution system is entirely interconnected, such that water entering the network from any one of the booster stations could reach any point in the system. The locations of the District's storage reservoirs and booster pumping stations are shown on Figure 3-1.

Table 3-2 illustrates the composition of the maximum daily flows in the past two years. While a minor portion of the demand occurred in the area north of 80th Avenue, it is assumed that the entire demand occurs south of 80th Avenue. This assumption provides a minor safety factor in the sizing of the proposed water treatment facility.

TABLE 3-2

MAXIMUM DAILY DEMAND IN THE
SOUTH ADAMS COUNTY WATER AND SANITATION DISTRICT
(All Flows in mgd)

Year	Peak 24-Hour Demand	Portion Provided from Shallow Wells	Portion Provided from Deep Wells
1985	9.6	9.1	0.5
1986	10.6	9.8	0.8

Table 3-3 presents the computation of the anticipated fully developed, maximum daily demand in the District south of 80th Avenue. Figure 3-1 indicates this area. Based upon an assumption that the deep wells would continue to supply approximately 0.8 mgd on future peak days, a supply of 12 mgd must be provided from the shallow wells.

4. TREATMENT FACILITY CAPACITY. The configuration of the well-storage-booster system allows the wells to pump at relatively constant rates on a continuous basis. The reservoir levels rise during evening hours and draw down during high use periods. The booster pumps must discharge into the distribution system at rates that match the instantaneous demand. The well pumps must have capacity to serve the anticipated maximum daily demand, while the booster pumps must meet the maximum hourly demand. The water treatment facility will be located between the wells and the storage reservoirs, so that the plant can be sized for the maximum day, rather than the maximum hour.

TABLE 3-3

ANTICIPATED FULLY DEVELOPED MAXIMUM DAILY DEMAND
SOUTH OF 80TH AVENUE IN THE
SOUTH ADAMS COUNTY WATER AND SANITATION DISTRICT
(All Flows in mgd)

	Demand	Portion Supplied From Shallow Wells	Portion Supplied From Deep Wells
Actual Maximum Daily Demand in 1986	10.6	9.8	0.8
Demand Anticipated in 1987 Due to Increase of 190 New Taps (2.9% increase)	10.9	10.1	0.8
Anticipated Ultimate Demand Assuming Full Development of Land Presently Undeveloped in the District's Service Area South of 80th Avenue	12.8	12.0	0.8

The preceding sections indicate that the fully developed demand upon the shallow well supply is anticipated to reach 12 mgd and that the shallow well supply in the southern portion of the District can be improved to approximately 12 mgd. Therefore, it is recommended that a nominal capacity of 12 mgd be adopted for the water treatment facility.

B. WATER QUALITY AND REGULATORY REQUIREMENTS

In this section, water quality data and drinking water regulations with regard to volatile organic chemicals (VOCs) are reviewed and discussed.

1. REGULATORY REQUIREMENTS. The Safe Drinking Water Act Amendments of 1986 recently adopted rules for developing standards for contaminants in drinking water supplies.

The Federal regulations have proposed maximum contaminant levels (MCLs) and recommended MCLs (RMCLs) for eight VOCs. They also published RMCLs for 37 synthetic organic chemicals (SOCs) (plus two by-products), four microbiological contaminants, 11 inorganics, plus proposals for mandatory filtration of surface waters and disinfection of ground water. The regulated VOCs and SOCs, along with the proposed MCLs and RMCLs, have been listed in the 1986 Treatment/Feasibility Study. For the purposes of this study, it should be noted that these Federal regulations have proposed an RMCL of zero and an MCL of 5 ug/l for trichloroethylene (TCE).

2. WATER QUALITY. The 1986 Treatability/Feasibility Study reported the types and concentrations of organic contaminants observed in the existing water supply wells. Table 3-4 summarizes the previous information and indicates the average and maximum concentrations detected in the shallow wells for each organic compound. As indicated by the table, the predominant contaminant of concern is TCE. Information from previous and more recent sampling, performed to monitor the TCE concentrations at each of the District's supply wells, is shown in Table 3-5. The data represents sampling performed between May 1984 and September 1986.

TABLE 3-4

AVERAGE AND MAXIMUM CONCENTRATIONS OF ORGANIC CONTAMINANTS IN EXISTING WELLS[1]

	Shallow Well Concentrations, ug/l	
	Average	Maximum
Trichloroethylene	16.1	27.7
Tetrachloroethylene	3.1	4.7
1, 1, 1 Trichloroethane	2.0	3.2
1, 1 Dichloroethene	0.9	2.5
1, 2 Dichloroethene	1.1	2.2
Methylene Chloride	2.6	5.6
Dibromochloromethane	0.1	0.1
Bromoform	0.9	2.7
Benzene	0.1	0.1
Toluene	0.1	0.3
1, 1 Dechloroethene	0.3	0.9
Chloroform	0.1	0.1

[1] From "Treatability/Feasibility Study for District Water Quality Improvement", by James M. Montgomery, Consulting Engineers, 1986, except for TCE data.

TABLE 3-5

TCE CONCENTRATIONS IN EXISTING SHALLOW WELLS

Well Number	Trichloroethylene Concentration, ug/l	
	Average	Maximum
2	26.0	42
3	38.5	51
5	7.1	11
14	19.3	57
15	1.3	4
16	11.6	15
17	8.6	14

The average concentrations reported in Table 3-5 give an indication of the frequency of the reported maximum concentrations. An average and maximum concentration near the same value suggests that the well samples had fairly consistent levels of contamination.

The water quality characteristics that have been assumed for design criteria of the treatment facilities under consideration in this study are summarized in Table 3-6. Utilizing the assumed TCE design concentrations, projected monthly flow rates for 1987 and ultimate service area demands, and an assumed well pumping schedule, the following average annual, flow weighted, TCE concentrations were determined:

	Annual Average TCE Design Concentrations, ug/l			
	Average Annual Flow (mgd)	Average	Maximum	Design
1987 Demand	3.8	32.3	45.8	95.7
Ultimate Demand	6.9	25.2	39.7	76.7

The concentrations are based on a pumping schedule which meets demands with the most contaminated well available. Therefore, the above concentrations represent the maximum values possible through blending of alternative well sources.

TABLE 3-6

ASSUMED WATER QUALITY CHARACTERISTICS

Well Number	TCE Concentration Assumed for Design Criteria, ug/l		
	Average[1]	Maximum[1]	Design[2]
2	26	42	100
3	39	51	100
5	7	11	20
14	19	57	100
15	1	4	20
16	12	15	20
17	9	14	20

[1] Average and maximum concentrations represent contamination levels measured to date.

[2] Design concentrations represent future estimated contamination levels for each of the wells as predicted in the 1986 Treatability/Feasibility Study.

CHAPTER 4

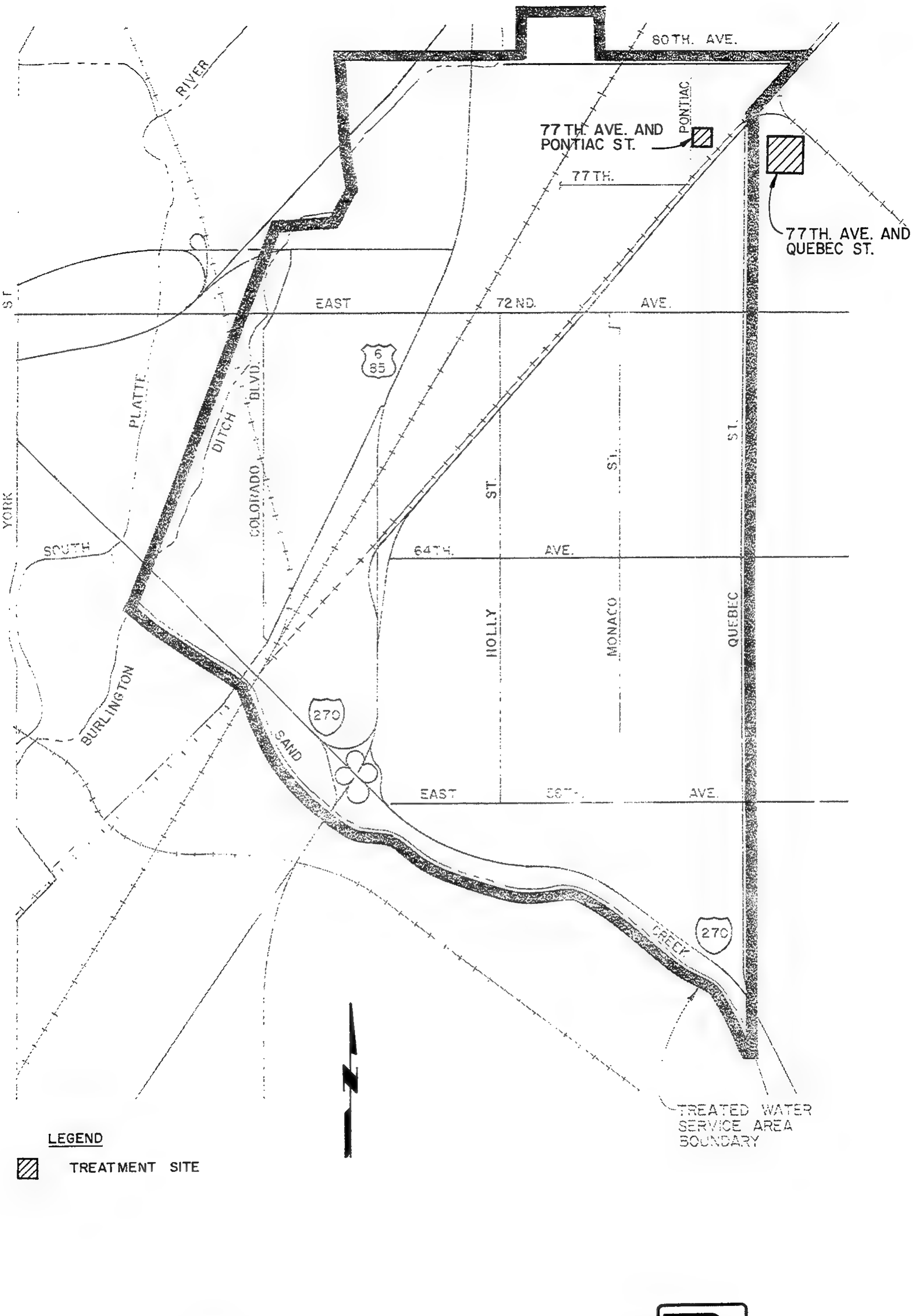
GRANULAR ACTIVATED CARBON ADSORPTION TREATMENT ALTERNATIVES

A. CENTRALIZED FACILITY SITE ALTERNATIVES

Two alternative sites were evaluated in determining a location for centralized treatment facilities. As shown on Figure 4-1, the first site is located east of Quebec Street at 77th Avenue on Rocky Mountain Arsenal property. The alternate site is located at 77th Avenue and Pontiac Street adjacent to the District's well, storage tank, and booster pumping station. These sites were selected for evaluation based on their proximity to the two major water supply wells at 77th Avenue and Quebec Street and 77th Avenue and Pontiac Street, and because these sites presently are undeveloped.

The 77th Avenue and Quebec Street site, referred to henceforth as the Quebec Street site, has many attractive features which make it the desired location. The Rocky Mountain Arsenal has expressed a willingness to make land available at the Quebec Street site for the treatment facility. Current negotiations between the Army and District indicate that the land may possibly be made available through a minimal cost, long-term lease. The site has sufficient space available to permit construction of facilities to treat the present levels of ground water contamination as well as adding future units in the event higher concentration levels of the existing contaminates or additional contaminates are detected. Access to the Quebec Street site is made direct and convenient from major highway arteries by both Quebec Street and Colorado State Highway No. 2. The site is also adjacent to a railroad spur which presently serves the Arsenal.

During the course of the study, it was learned that Commerce City is evaluating the future addition of a north-south expressway adjacent to and east of existing Quebec Street. The Quebec Street treatment facility site will be located to integrate into the proposed expressway development plans.



TREATMENT FACILITY SITES

Figure 4 -1

The Quebec Street right-of-way provides the easement necessary to install the transmission pipelines connecting the District wells and storage tanks with the new treatment facility. The Quebec Street site provides direct access to this easement.

The evaluation of the 77th Avenue and Pontiac site revealed several important disadvantages which make the site undesirable. The site is privately owned and will have to be acquired prior to construction. The land available for construction is sufficient only to site facilities capable of treating existing contaminant concentration levels. Future expansion would be very difficult. The site is bordered on two sides with residential housing. Site access is through narrow residential streets.

As noted previously, the site evaluation has resulted in the Quebec Street site being selected as the desired location for a centralized treatment facility.

B. EVALUATION OF CENTRALIZED VERSUS DECENTRALIZED TREATMENT FACILITIES

A cost evaluation of centralized versus decentralized treatment facilities was performed to determine the most economical and feasible treatment approach. The location for the centralized facilities is at the Quebec Street site previously recommended. The treatment capacity of the plant is approximately 12.0 mgd. The water transmission and pumping system modifications recommended in Chapter 5 and indicated on Figure 5-1 are included in the costs for the centralized facility. The decentralized alternative consists of two separate treatment plants. The northern facility is located on 3-1/2 acres, currently undeveloped, adjacent the 77th Avenue and Pontiac Street well, storage tank, and booster pumping station. The treatment capacity of the plant is approximately 4.0 mgd. The southern decentralized facility is located on Rocky Mountain Arsenal property just east of 64th Avenue and Quebec Street. This plant has a treatment capacity of approximatly 8.0 mgd. The southern site also is the location of the administration and laboratory support buildings. Figure 5-3, in Chapter 5, indicates the water transmission and pumping modifications required for the decentralized treatment alternative.

The centralized and decentralized treatment plants have GAC downflow pressure vessels operating in parallel. The effluent from all of the carbon contactors is blended to achieve maximum carbon usage and to meet drinking water standards.

The cost comparison between centralized and decentralized treatment facilities is indicated in Table 4-1. The centralized treatment plant alternative realizes a slight capital cost savings over decentralized facilities. Additional advantages of a single treatment plant include:

- A single treatment plant will be able to achieve greater carbon utilization rates than decentralized facilities. A single plant will have a greater number of GAC contactors in parallel than decentralized facilities and, therefore, will be able to more fully utilize the carbon bed in each contactor and still meet drinking water standards for the combined effluent. This advantage will result in the single treatment facility having significantly lower O&M costs for carbon replacement.

- A single treatment plant avoids the duplication of capital costs at two facilities for such items as reserve GAC pressure vessels, emergency electrical power, backwash pumping and holding tanks, chlorination facilities, and site acquisition and development improvements.

- A single plant requires less operating and maintenance expenses for heating, lighting, and general plant maintenance.

- A single plant will allow better control of treatment operations.

- A single plant could be more economically expanded in the future, if necessary, than the expansion of two separate facilities.

Because of the cost savings and operational advantages, a centralized treatment facility is recommended over the decentralized alternative.

C. GAC CONTACTOR DESIGN CONSIDERATIONS

Selection of the appropriate type and configuration of contactor and associated support equipment is essential in the design of a cost-effective carbon adsorption system. This section presents a general overview of contactor design considerations and an evaluation of applicable contactor configuration alternatives.

TABLE 4-1

CENTRALIZED VERSUS DECENTRALIZED TREATMENT FACILITIES

Decentralized Facilities

77th and Pontiac Treatment Plant	
6 GAC Pressure Vessels and Piping	$ 864,000
Backwash Piping and Holding Tank	85,000
Initial Carbon Loading	240,000
Building for GAC Units	810,000
Chemical Building	130,000
Chlorine, Ammonia, and Chemical Feed Equipment	115,000
Electrical and Instrumentation	245,000
Water Transmission Modifications	57,000
Site Acquisition	155,000
Site Improvements	165,000
SITE TOTAL	$ 2,866,000
64th and Quebec Treatment Plant	
12 GAC Pressure Vessels and Piping	$ 1,728,000
Backwash Piping and Holding Tank	85,000
Initial Carbon Loading	240,000
Building for GAC Units	1,138,000
Chemical Storage and Maintenance Building	175,000
Chlorine, Ammonia, and Chemical Feed Equipment	115,000
Electrical and Instrumentation	345,000
Water Transmission Modifications	296,000
Administration and Laboratory Building	390,000
GC/MS Laboratory Equipment	235,000
Site Acquisition(1)	0
Site Improvements	230,000
SITE TOTAL	$ 4,977,000
Capital Cost of Decentralized Facilities	$ 7,843,000
Design Engineering (8%)	627,000
Construction Engineering (5%)	392,000
TOTAL COST	$ 8,862,000

TABLE 4-1

CENTRALIZED VERSUS DECENTRALIZED TREATMENT FACILITIES
(Continued)

Centralized Facility[2]	
18 GAC Pressure Vessels and Piping	$ 2,592,000
Backwash Piping and Holding Tank	120,000
Initial Carbon Loading	360,000
Building for GAC Units	1,360,000
Chemical Storage and Maintenance Building	175,000
Chlorine, Ammonia, and Chemical Feed Equipment	155,000
Electrical and Instrumentation	485,000
Water System Modifications	1,469,000
Administration and Laboratory Building	390,000
GC/MS Laboratory Equipment	235,000
Site Acquisition[1]	0
Site Improvements	285,000
Capital Cost of Centralized Facilities	$ 7,626,000
Design Engineering (8%)	610,000
Construction Engineering (5%)	381,000
TOTAL COST	$ 8,617,000

[1] This alternative would request the Army provide 10 acres of land for the treatment facility. This item may be increased in the future if a minimal cost, long-term lease cannot be arranged.

[2] Capital cost items correspond to the recommended treatment facility presented in Chapter 7.

1. GENERAL DESIGN CONSIDERATIONS.

a. Contactor Behavior. A general discussion of adsorption contactor behavior is presented herein in order to illustrate typical design considerations and to define the basis for subsequent evaluation of various contactor configurations. The general discussion of adsorption contactor behavior which follows assumes a downflow, fixed-bed configuration.

When the water to be treated is introduced at the top of a contactor containing fresh activated carbon, most of the organic contaminants present in the feedwater are removed by the carbon in a narrow zone at the top of the bed. Organics which are not removed immediately are typically adsorbed as they pass through subsequent levels of the bed. Depending upon the design of the contactor system, the characteristics of the carbon, and the nature of the organic contaminants to be removed, all of the contaminants are typically removed before the process stream reaches the contactor discharge point. The region of the carbon bed where adsorption of the organic contaminants occurs is typically referred to as the "adsorption zone" or the "mass transfer zone". As the capacity of the carbon in the upper levels of the bed is consumed, the mass transfer zone moves further into the bed in a wavelike manner. As the adsorptive capacity of the bed gradually becomes exhausted and the leading edge of the mass transfer zone approaches the contactor effluent, increasingly greater concentrations of organics appear in the contactor effluent. The point at which the effluent organic concentration reaches the maximum allowable level (i.e., the treatment objective) is typically referred to as "breakthrough". The point at which effluent organic concentration is equivalent to that of the contactor feedwater is referred to as "exhaustion", as the carbon's ability to remove any additional organic contaminants from the feedwater has been exhausted.

The relative depth of the mass transfer zone is unique for each compound to be removed and can vary from several inches for readily-adsorbable compounds present in low concentrations to greater than 10 feet for some high-strength wastes. The contaminant of predominant concern in the District's well supply is trichloroethylene (TCE) which exhibits a well-defined mass transfer zone having an overall length of approximately 4 feet.

Ideal contactor operation occurs when the point of organic breakthrough coincides with carbon exhaustion. This results in maximum utilization of the carbon's available adsorption sites, and therefore minimizes costs for carbon replacement or regeneration. Single-bed adsorption contactors removing compounds which exhibit relatively long mass transfer zone characteristics typically do not achieve high carbon utilization rates, as breakthrough occurs well in advance of complete carbon exhaustion.

b. Carbon Fines Removal. Provisions for flushing of carbon fines from the contactor following initial carbon loading and after replacement of spent carbon with fresh carbon are required to minimize the migration of fines into contactor effluent. Removal of fines is also required in order to minimize excessive initial hydraulic head losses through the contactor carbon bed. For fixed-bed contactors, this is typically accomplished by upflow backflushing at a rate of 2 to 3 gpm per square foot of contactor area for about five minutes. Disposal of backflush flows usually consists of discharge to the sanitary sewer system. As the carbon fines exhibit poor settling characteristics, separation of fines from the backflush flow and subsequent recycling of the flow is not considered a feasible disposal alternative.

District facilities would discharge flows to the sanitary sewer system. Carbon fines will have a negligible or possibly even beneficial impact on the wastewater treatment plant.

c. Microbiological Activity Control. Experience at existing facilties indicates that granular activated carbon contactors represent an ideal environment for the development of microbiological activity. Researchers have concluded that some microbial activity is typically beneficial to the operation of the contactor, as the microorganisms may oxidize biodegradable organics into carbon and water. This oxidation process leads to a reduction in the effective organics loading on the carbon and thus to increased contactor run times. The effectiveness of the oxidation process is dependent in large part on the quantity and degradability of the organics in the raw water supply, carbon type and quality, and the empty-bed contact time (EBCT) provided.

However, excessive development of microbial populations within carbon contactors may lead to a number of undesirable conditions, such as increased colony counts in the treated water and biodegradation of influent organics into potentially harmful compounds which are not readily adsorbable. Therefore, provisions for control of microbial activity within the adsorbers should be included. Control measures typically include provisions for disinfection (either continuously at low dosage rates or periodically at high dosages) and high-rate backwash capability for removal of biological accumulations.

An additional consideration in the control of microbial activity is the potential problems associated with intermittent operation of the adsorption units. Activated carbon's ability to remove essentially all of the dissolved oxygen from the feedwater will lead to the development of anaerobic conditions in off-line contactors unless provisions are made for column disinfection prior to storage. If anaerobic conditions do develop, formation of odorous compounds such as hydrogen sulfide and/or growth of undesirable anaerobic microorganisms within the bed may be unavoidable. It is, therefore, important to minimize or avoid stoppage of feedwater flows through the contactors for extended periods. Should removal of a contactor from service for an extended period become necessary, dewatering of the saturated carbon and disinfection of the carbon bed with chloramines and/or sodium hydroxide solutions will be required.

In order to control potential microbiological activity in the contactors at the District's treatment plant, it is recommended that the disinfection system have the capability of adding low doses of chloramines to the raw water supply prior to the contactors and high doses during backwash cycles. Additionally, the chlorination facilities should be able to be utilized to disinfect an empty contactor after internal vessel maintenance or lining repair has been performed.

d. Contactor Backwash. Provisions for high-rate backwashing of fixed-bed contactors are typically provided when any of the following conditions exist:

- Raw water suspended solids/turbidity levels are such that accumulation of solids within the carbon bed (and therefore development of high head losses through the bed) would limit contactor run times (i.e., the length of time between carbon replacement).

- Insoluble iron and/or manganese are present in the raw water supply at levels which may lead to excessive solids deposition within the bed and/or "plating" of carbon surfaces.

- The potential for microbiological activity within the contactor is such that periodic backwashing may be required to remove biological accumulations.

Backwash rates are dependent upon the selected carbon gradation and wash water temperatures and generally range from 5 to 20 gpm per square foot of contactor area. If the need for contactor backwashing is based upon excessive solids accumulations within the contactor, the wash water may be recycled to the front end of the plant following separation of the solids from the wash water by gravity settling. However, if periodic backwashing is required for removal of biological accumulations, recycle of the wash water is not recommended. Equalization and discharge to the sanitary sewer system at a controlled rate is then recommended.

Backwashing facilities are recommended for the District's contactors. Backwashing provisions are economically justifiable and operationally necessary for the following reasons:

- Although the well supply has low suspended solids concentrations, this does not preclude a break from occurring in a well screen or water supply line. The break and subsequent repair activities would most likely result in dirt and sand entering the supply line and consequently blinding the contactors. If backwash provisions were not provided, the only corrective action available would be the complete removal of all carbon beds; irregardless of their remaining service life. The cost of total replacement of carbon would be approximately $320,000 to correct a single accident. This amount is greater than the estimated $120,000 capital cost required to provide backwash facilities for the treatment plant.

- Based upon the current contamination level in the well supply, the carbon bed life is estimated to be over one year. Biological growth in the contactor is anticipated with such an extended carbon life. Backwash facilities are necessary in order to periodically remove biological accumulations through expansion of the carbon bed and scouring. Additionally, if necessary, biological growth can be controlled in the carbon bed by disinfecting the contactor with high doses of chloramines during backwashing cycles.

- Backwashing and expansion of the carbon bed prior to/and during the removal of exhausted carbon out of the contactor greatly improves carbon transfer operations.

e. Gravity Versus Pressure Contactors. Both gravity and pressure contactors have been successfully utilized in carbon adsorption applications. The relative advantages and disadvantages associated with the use of these designs are presented below:

- Construction Materials. Pressure contactors are of steel construction, while gravity contactors are generally made of concrete. Concrete construction eliminates potential corrosion problems and typically leads to longer contactor effective service life.

- Contactor Size. Shipping regulations limit the diameter of prefabricated steel pressure vessels to 12 feet. Concrete contactors can be constructed in essentially any size desired, and common wall construction can be utilized. Extensive underground pipe galleries are required for concrete contactors to provide access to carbon transfer and effluent underdrain valves and piping.

- Hydraulic Considerations. Gravity contactor available head loss is limited by the effective depth of the contactor structure. Clearwell storage and pumping facilities must be provided immediately downstream of gravity contactors. Use of gravity contactors requires that high service pumping to the distribution system be provided from the clearwell. Pressure contactors can generally tolerate higher hydraulic head losses prior to needing backwashing and/or carbon replacement. Use of pressure contactors may eliminate the need for clearwell storage and repumping of treated water prior to distribution (i.e., the well pumps provide sufficient pressure to pass the raw water through the contactors and on into the distribution system).

- Operation. For gravity contactors, the operator can directly observe the surface of the bed, and can therefore determine that the rate of wash water application during backwash is correct and that wash water is evenly distributed. Direct observation is not possible for pressure contactors. However, for ground water systems which exhibit low suspended solids concentrations, this factor is not generally significant since backwashing occurs only periodically and can typically be accomplished using low backwash flow rates.

- Interface Piping. Use of smaller pressure contactors requires increased numbers of contactors and therefore increased interface piping and valve requirements.

- Construction Time. When rapid facility construction time is a major consideration, use of prefabricated pressure units can significantly accelerate plant construction schedules. Gravity concrete contactors require considerably more design and construction time.

The use of pressure contactors is recommended for the District's treatment facility. Prefabricated steel units are recommended in order to reduce plant construction times. As described in Chapter 5, the use of pressure contactors eliminates the need for the treatment plant to provide clearwell storage and pumping to the distribution system. The cost comparison between gravity and pressure contactor treatment facilities is indicated in Table 4-2. The pressurized contactor alternative realizes significant capital cost savings over gravity contactors. The gravity contactor alternative becomes more cost competitive for larger treatment plant capacities and for greatly increased contamination levels requiring increased carbon volumes.

The annual maintenance costs for the steel pressure vessels are greater than required for the concrete gravity contactors. However, the gravity alternative would have additional maintenance costs associated with the pumping station. Overall there would not be any significant difference in the annual maintenance costs for the two systems.

f. Contactor Dimensions. Over-the-road shipments of granular activated carbon are currently limited to a maximum of 20,000 pounds (dry weight). Therefore, if the use of a contract carbon replacement/regeneration service is to be considered, contactor carbon loading must be limited to 20,000 pounds, or the use of multiple delivery trucks and/or provisions for on-site storage of both fresh and spent carbon will be required.

TABLE 4-2

GRAVITY VERSUS PRESSURE CONTACTORS[1]

	Costs ($)
Gravity Contractors	
Site Excavation and Foundation	$ 595,000
Gravity Contactors and Piping	3,340,000
Building for GAC Units	720,000
Clearwell Storage and Pumping Station	382,000
Water System Modifications	1,330,000
TOTAL	$6,367,000
Pressure Contactors	
Site Excavation and Foundation	$ 290,000
Pressure Contactors and Piping	2,592,000
Building for GAC Units	1,165,000
Water System Modifications	1,469,000
TOTAL	$5,516,000

[1] Based on 12 mgd treatment plant capacity. Only costs which are different for each alternative are compared.

Pressure contactor diameters were evaluated in detail to determine the optimum contactor dimensions for the treatment facility. The two alternatives considered were sixteen 10-foot diameter GAC units each containing 20,000 pounds of carbon and eleven 12-foot diameter GAC units each containing 30,000 pounds of carbon. The first alternative included two reserve contactors which could also be used for carbon storage. The second alternative included one reserve contactor and carbon storage facilities consisting of both fresh and spent carbon tanks each capable of holding 40,000 pounds of carbon. Table 4-3 indicates the cost evaluation of the two alternatives. Although the second alternative needs a fewer number of GAC units and reduced building area, the additional cost of carbon storage tanks (which also need to be enclosed to prevent freezing) results in no cost advantage to either alternative. Since the 12-foot diameter contactors require carbon storage, this alternative would necessitate two additional carbon transfer operations above the other alternative. These additional transfers are a severe disadvantage since significant amounts of carbon fines (and the corresponding carbon loss) are generated during each transfer. Another disadvantage is that the transfer procedure is a difficult and time-consuming maintenance operation which is extremely abrasive on piping and equipment. Because of the above operational considerations, 10-foot diameter pressure contactors are recommended for the treatment facility.

2. CONTACTOR CONFIGURATION ALTERNATIVES. Various contactor configurations have been developed in an attempt to maximize carbon utilization efficiencies. These contactor configurations and their relative advantages and disadvantages are discussed below.

a. Downflow, Fixed-Bed Contactor. This design is the predominant contactor configuration currently utilized in the treatment of contaminated ground water supplies. Downflow contactors can be designed to yield high carbon utilization rates when the mass transfer zone of the contaminant(s) to be removed is relatively short. As the carbon acts as a highly efficient filter media, any suspended solids present in the feedwater are removed in the contactor. Migration of any carbon fines to the contactor effluent is therefore minimized, and the need for post-adsorber filtration is eliminated. The contactors can be designed as either gravity flow or pressurized units,

TABLE 4-3

ALTERNATIVE CONTACTOR DIMENSIONS[1]

	Costs ($)
10-Foot Diameter Contactors	
18 GAC Units	$1,755,000
Building for GAC Units	1,360,000
Piping, Valves, and Instrumentation	837,000
TOTAL	$3,952,000
12-Foot Diameter Contactor	
12 GAC Units	$1,492,000
Building for GAC Units	1,102,000
Piping, Valves, and Instrumentation	828,000
Carbon Storage Tanks	295,000
Building for Carbon Storage Tanks	270,000
TOTAL	$3,987,000

[1] Based on 12 mgd treatment plant capacity. Only costs which are different for each alternative are compared.

depending on water supply system configuration. As the contactor is completely emptied during removal of spent GAC, the contactor lining and other internal components can be readily inspected. Potential disadvantages include somewhat greater land requirements than other contactor configurations, and a gradual degradation of effluent quality as the GAC within the column is exhausted. If the length of the mass transfer zone of the compounds to be removed is relatively long, downflow, fixed-bed contactors also may not provide acceptable carbon utilization rates due to rapid column breakthrough.

Downflow, fixed-bed pressure contactors are recommended for the District's facility. This system is the most reliable and the easiest to operate and maintain of all of the alternative configurations. Since few suspended solids are present in the ground water supplies, backwashing will probably be needed infrequently. By eliminating post-adsorber filtration, this contactor configuration is the least costly of the alternatives.

b. Upflow, Expanded-Bed Contactor. For this column configuration, the feedwater flows upward through the carbon at velocities sufficient to partially expand the bed. As the mass transfer zone moves upward through the bed, fresh GAC is added at the top of the contactor, and an equal amount of spent GAC is removed simultaneously from the bottom of the contactor. As the GAC within the contactor adsorbs increasing amounts of organic material, the carbon density increases, and the higher-density GAC migrates to the bottom of the contactor. Thus, the feedwater flows from regions of partially or fully-spent carbon to regions of relatively fresh GAC. Utilization of the carbon's adsorptive capacity is maximized, as the partially-spent GAC is continually moving toward regions of increasing organics concentration.

The primary disadvantage associated with the use of upflow expanded-bed contactors is their tendency to pass any suspended solids present in the feedwater directly through the contactor. Also, as the GAC bed is in an expanded state, continuous interparticle contact occurs, and carbon fines are generated. These carbon fines subsequently pass through the bed and into the treated water. Therefore, provisions for post-adsorber filtration must be included in the system.

The configuration is not recommended for the District's facility due to the operational complexity of the system and the additional capital costs required for post-adsorber filtration.

c. Upflow, Pulsed-Bed Contactor. While similar in operation to the upflow expanded-bed contactor configuration, the carbon bed in the pulsed-bed system is not allowed to expand. Therefore, flow velocities through the bed can be increased, resulting in reduced contactor area requirements. Similar to the upflow expanded-bed contactor, fresh GAC is added intermittently at the top of the contactor while simultaneously withdrawing an equivalent amount of GAC from the contactor bottom (i.e., "pulsing"). Typically, 5 to 10 percent of the total GAC volume is changed with each pulsing cycle. This system can be operated to achieve an effluent quality which is very close to the specified treatment objective on a continuous basis through control of pulse cycle frequency. This type of contactor also typically yields the highest carbon utilization rates for feedwaters which exhibit long mass transfer zone characteristics. However, some abrasion of the GAC occurs during pulsing operations, and therefore carbon fines may intermittently migrate to the contactor effluent, and post absorber filtration must be included in the system.

Potential disadvantages of the pulsed-bed system are the more complex operational and control aspects of the process, increased operator attention requirements, and the need for post-adsorber filtration for removal of carbon fines. Also, since the contactor is not completely emptied during GAC replacement, inspection of contactor internal components requires that all GAC be removed and temporarily stored. Intermittent pulsing also tends to disrupt the mass transfer zone due to intermixing of fresh and partially-spent carbon.

This configuration is also not recommended for the District's facility due to the operational complexity of the system and the additional capital costs required for post-adsorber filtration.

d. Series Versus Parallel Operation. For the removal of contaminants which exhibit relatively long mass transfer zones, use of two (or more) contactors in series can yield increased carbon utilization rates, and therefore reduced operations and maintenance costs. The first bed in the series receives the highest organics loading and is the first to reach

exhaustion. The second bed in the series serves as a polishing unit, allowing the first bed to be operated to complete exhaustion while maintaining the desired final effluent quality. When the first bed reaches exhaustion, it is removed from service and the carbon is replaced. The bed is then returned to service as the second polishing unit. The carbon contactors move counter-current to the process flow, thereby, fully utilizing the carbon's adsorptive capacity.

Parallel contactor configurations are typically utilized where the mass transfer zone of the contaminant(s) to be removed is short, and the time period between column breakthrough and exhaustion is not excessive. Depending upon system configuration and operational demands, startup of the beds can be staged such that exhaustion occurs sequentially. Therefore, effluent from both fresh and partially exhausted beds can be blended to achieve the desired final effluent quality meeting drinking water standards.

Piping and valving requirements for series operation are significantly more complex than for parallel contactor operation. The additional cost can typically be justified only when the degree of carbon utilization realized during series operation is much greater than can be obtained using parallel operation. Single-stage parallel contactor configurations are generally regarded as the most-applicable alternative for removal of volatile organic contaminants from ground water supplies, as mass transfer zone lengths are short, concentrations of organics are low, and breakthrough characteristics are typically well-defined.

D. RECOMMENDED CONTACTOR CONFIGURATION

The contaminant of predominant concern currently in the District's well supply is TCE. As TCE exhibits a short and well-defined mass transfer zone, provisions for series contactor operation will not be required in order to obtain acceptable carbon utilization rates. Therefore, the use of downflow pressure contactors operating in parallel is recommended for the District's treatment facility.

The recommended design criteria for the GAC vessels is indicated in Table 4-4. Figure 4-2 indicates the treatment process schematic for a GAC contactor.

E. CARBON USAGE

A primary factor in the overall operations cost of a carbon adsorption facility is the relative efficiency of carbon utilization, or carbon usage rate. Carbon usage rate is dependent upon feedwater organics concentrations, treatment objectives, and contactor design and configuration.

Three independent data sources were utilized in the development of projected carbon usage estimates for the District's treatment facility. These sources are as follows:

- Carbon usage rates as predicted by an adsorption model developed by Clark, Eilers, and Goodrich (1984). Reference: R. M. Clark, R. M., R. G. Eilers, and J .A. Goodrich, "VOCs in Drinking Water: Cost of Removal," Journal of the Environmental Engineering Division, ASCE, Vol. 110, No. 6, December 1984.

- Results of Accelerated Column Test (ACT) analyses conducted by Calgon Carbon Corporation.

- Usage rates as predicted by the homogenous surface diffusion model (simplified numerical solution method) developed by Hand, Crittenden, and Thacker (1984). References: D. W. Hand, J. C. Crittenden, and W. E. Thacker, "Simplified Models for Design of Fixed Bed Adsorption Systems", Journal of the Environmental Engineering Division, ASCE, Vol. 110, No. 2, April 1984.

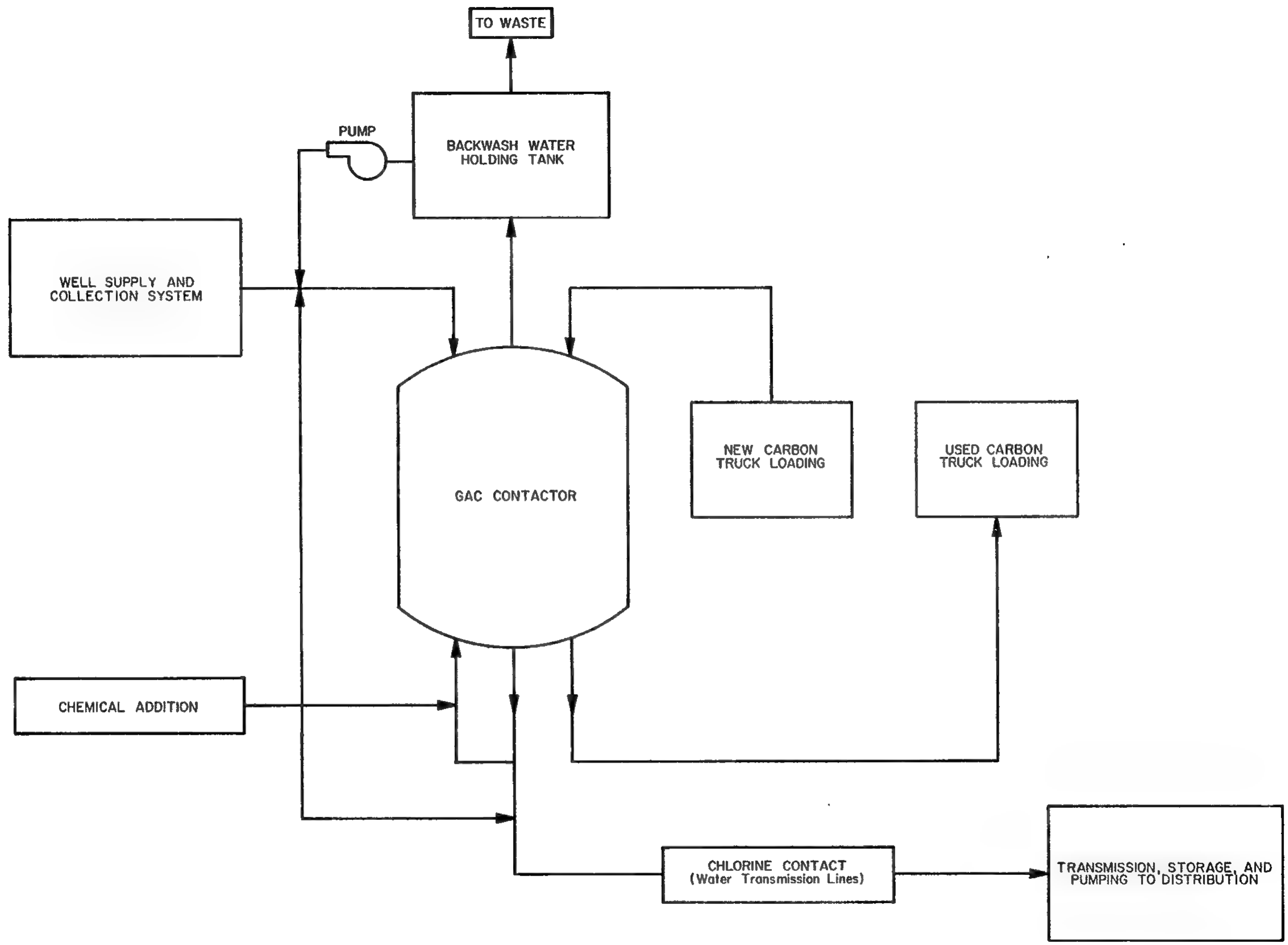
Details of each of the above methods of analysis and projected carbon usage rates are presented below.

1. CLARK, EILERS, AND GOODRICH MODEL. The Clark, Eilers, and Goodrich (CEG) model was developed through regression analysis of both laboratory isotherm data for removal of volatile organic compounds and actual pilot-scale testing data. The model relates carbon usage to influent organics concentrations, desired removal efficiency, and the physical characteristics of the compound to be removed. The relationship is as follows:

TABLE 4-4

GAC CONTACTOR DESIGN CRITERIA

Item	Value
Pressure Contactors	
12 mgd Treatment Capacity	16
Reserve Capacity	2
Diameter, ft	10
Height, ft	
Carbon Bed Depth	9
Minimum Sidewall Depth	12
Loading Rate, gpm/ft^2	
Average Day	3.8
Maximum Day	6.6
Empty Bed Contact Time, minutes	
Average Day	18
Maximum Day	10



GAC TREATMENT PROCESS SCHEMATIC

Figure 4-2

$$UR = 100.1 \times RM^{4.52} \times IF^{0.31} \times ML^{-1.94} \times SL^{0.31}$$

where UR is pounds of GAC per thousand gallons of water treated, RM is the removal percentage as a decimal, IF is the influent concentration of the contaminant to be removed in micrograms per liter, ML is the molecular weight of the compound in grams per mole, and SL is the solubility of the compound in milligrams per liter. For removal of TCE, ML = 132 grams per mole, and SL = 1,000 milligrams per liter.

Assuming removal of TCE to effluent concentrations of 10 ug/l (estimated effluent from partially exhausted contactors which can then be blended with effluent from fresh units to achieve drinking water standards), 5 ug/l (the current MCL), and 1 ug/l (a value which approaches the current RMCL of 0 ug/l); projected carbon usage rates for various influent TCE levels are as follows:

Influent TCE (ug/l)	Carbon Usage, pounds per 1,000 gallons		
	10 ug/l Effluent	5 ug/l Effluent	1 ug/l Effluent
10	-	0.006	0.083
30	0.030	0.082	0.162
50	0.080	0.137	0.201
100	0.170	0.217	0.261
150	0.227	0.246	0.296

Based on the projected 1987 average influent TCE concentration of 30 to 35 ug/l, carbon usage would be estimated by the CEG model to be about 0.04 pounds per 1,000 gallons for removal to an effluent TCE level of 10 ug/l, and approximately 0.09 pounds per 1,000 gallons for removal to 5 ug/lg and approximately 0.17 pounds per 1,000 gallons for removal to 1 ug/l.

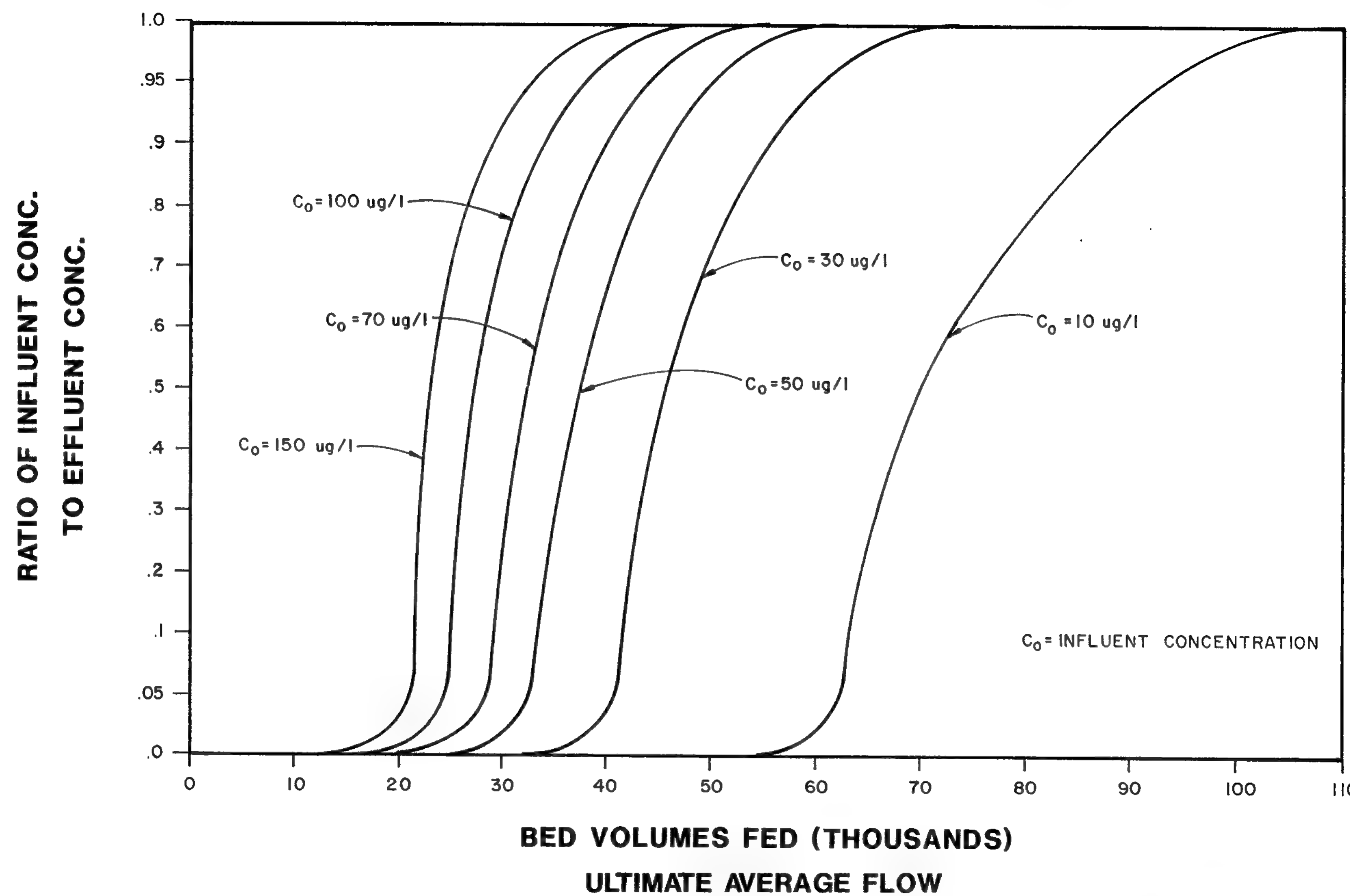
2. ACCELERATED COLUMN TESTING. Calgon Carbon Corporation has conducted ACT analyses on water from the District's well supply system. The ACT was developed to overcome the limitations of laboratory isotherm analyses and to utilize the capabilities of highly-predictive but time-consuming pilot adsorption column testing. While aquisition of representative data from conventional pilot contactors may require several months, the ACT procedure typically requires only several days. Independent researchers have concluded that the results obtained from the ACT closely approximate the results obtained through conventional pilot testing in most cases.

Initial ACT testing consisted of analysis of two water samples. The two samples exhibited TCE concentrations of 4 ug/l and 19 ug/l. Sample volume limited the "equivalent" column run length to about 88 days, at which time the test was terminated. Breakthrough of TCE to the column effluent did not occur for either sample. As the samples were consumed prior to breakthrough, the results of the testing are considered inconclusive. However, the testing did indicate that carbon usage would be less than approximately 0.32 pounds per 1,000 gallons treated for both well supplies tested.

A third ACT analysis was performed on well water with a TCE concentration of 36 ug/l. In order to minimize the potential for complete consumption of the sample prior to column breakthrough, multiple columns, each containing differing amounts of GAC, were operated in parallel. Results indicate that a carbon usage rate of about 0.08 pounds per 1,000 gallons treated can be expected. Assuming a contactor with 20,000 pounds of carbon operating at an average loading of 5 gpm per square foot, projected contactor run time would be approximately 440 days prior to initial breakthrough.

3. HOMOGENOUS SURFACE DIFFUSION MODEL (HSDM). The Homogenous Surface Diffusion Model (HSDM) uses fixed bed adsorber dynamics to predict the impact of carbon adsorption process variables on contactor performance. Accordingly, the HSDM is useful in simulating the effluent concentration history profile for differing GAC treatment conditions.

Analytical and numerical solutions to the HSDM were able to predict breakthrough curves for various TCE concentrations. The figures are based upon the ultimate average monthly flows projected for the District. Figure 4-3 indicates the simulated breakthrough profile as a function of



GAC BREAKTHROUGH CURVE

Figure 4-3

bed volumes fed through the contactor and influent TCE levels. Figure 4-4 indicates the breakthrough curves for the concentrations as a function of time. From the HSDM data, estimated carbon usage rates were determined for various influent TCE levels as follows:

Influent TCE (mg/l)	Carbon Usage, pounds per 1,000 gallons		
	10 ug/l Effluent	5 ug/l Effluent	1 ug/l Effluent
10	0.04	0.05	0.06
30	0.08	0.09	0.09
50	0.11	0.11	0.12
100	0.15	0.15	0.16
150	0.18	0.19	0.20

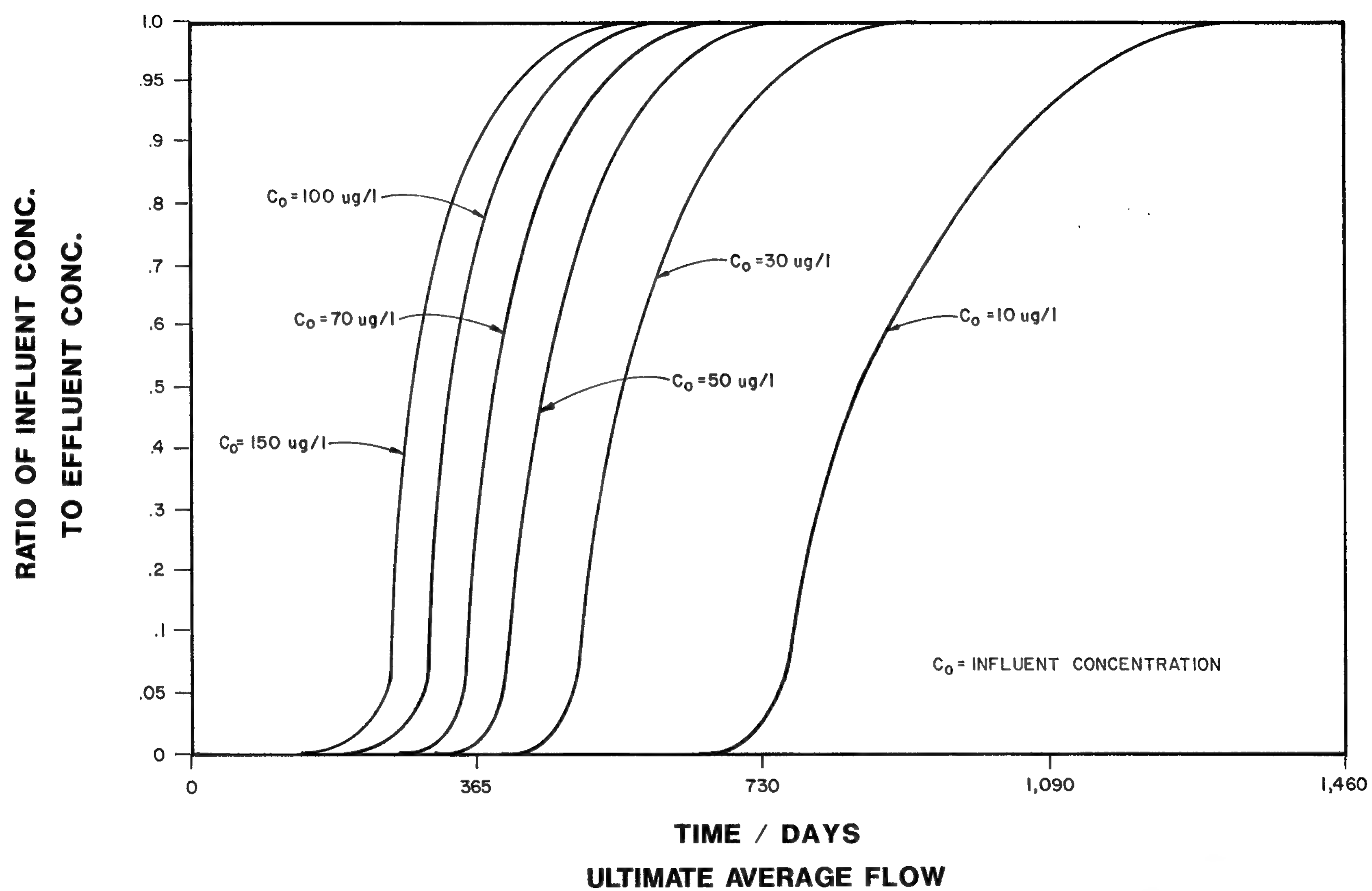
4. PROJECTED CARBON USE RATE. Based on the above, the projected average carbon use rate is assumed to be approximately 0.08 pounds per 1,000 gallons treated. This projection assumes that the contaminant levels in the well supply remain at existing concentrations. If the contaminant levels increase, the carbon use rate will also increase.

F. CARBON REPLACEMENT

When the adsorptive capacity of the carbon is exhausted, replacement with fresh carbon is required. Three replacement alternatives for the District's treatment facility were evaluated. These alternatives are as follows:

- Carbon replacement and ultimate disposal of spent carbon by District personnel.
- On-site regeneration of spent carbon.
- Use of a contract replacement/regeneration service.

The relative advantages and disadvantages of each of these alternatives are discussed in this section.



GAC BREAKTHROUGH CURVE

Figure 4-4

1. DISTRICT REPLACEMENT AND DISPOSAL. For this alternative, spent GAC would be removed from the contactors and disposed of by District personnel. Carbon would be received in bulk trucks. This alternative would have the following disadvantages:

- Purchase or leasing of vehicles for approved transport of spent GAC to the ultimate disposal site would be required. Landfill disposal costs would most likely be required by this alternative.
- The District would be legally responsible for the ultimate disposal of spent GAC in a safe and approved manner. The District may be exposed to long-term liability depending upon the ultimate disposal alternative selected and future regulatory requirements.

Based on the above considerations, GAC replacement and disposal by District personnel is not recommended.

2. ON-SITE CARBON REGENERATION. For this alternative, spent GAC would be removed from the contactors and thermally-regenerated on-site. Equipment requirements would consist of a multiple-hearth or infared regeneration furnace, storage bins for both fresh/regenerated carbon and spent carbon, spent and regenerated carbon transport facilities, and associated carbon slurry pumping equipment.

The relative cost-effectiveness of an on-site regeneration facility is primarily dependent upon the average daily carbon use rate. Experience at operating installations has led to the general conclusion that on-site regeneration is not typically cost-effective at carbon consumption rates of less than 2,000 pounds per day. As a major portion of the operations cost of the regeneration furnace is related to fuel requirements for bringing the furnace from a shutdown condition to full operating temperature, frequent on-off cycles must be avoided. Therefore, optimum performance and cost-effectiveness is not realized unless a relatively continuous feed of GAC to the furnace is maintained.

Demand projections indicate that the annual average daily flow treated during initial plant operation would be approximately 3.8 mgd. The annual average daily flow would increase to about 6.9 mgd at ultimate plant flow rates. Assuming an average carbon usage rate of 0.1 pounds per 1,000 gallons

treated, annual average daily carbon consumption would range from 380 pounds initially to 690 pounds per day at ultimate plant flows. These values are considerably less than the previously discussed 2,000 pounds per day minimum recommended carbon consumption required for cost-effective on-site regeneration. Also, based on projected contactor run times and TCE breakthrough characteristics, operation of regeneration equipment would not be required on a continuous basis. Significant capital expenditure would, therefore, be required for equipment which might operate for less than half of the year. The District would also be responsible for maintaining air quality/emissions standards during operation of the regeneration facility.

Based on the above considerations, on-site regeneration of carbon is not considered to be a practical or economical alternative for carbon replacement at this time. However, should additional carbon adsorption capacity be constructed by the District in the future, the feasibility of a central regeneration facilty should be re-evaluated.

3. CONTRACT CARBON REPLACEMENT/REGENERATION. For this alternative, the District would utilize a commercial carbon replacement service for removal of spent carbon and replacement with fresh carbon. Regeneration or approved disposal of the spent carbon would therefore become the responsibility of the contractor. The scope of services provided by the contractor typically includes removal and replacement of spent carbon and indemnification of the District against any future liability over the disposal of the spent carbon.

Advantages associated with the use of a contract carbon service include the following:

- Capital expenditure can be minimized through elimination (if desired) of on-site carbon storage and the associated transfer piping and equipment. All carbon transfer operations would be carried out utilizing transfer piping directly connecting the GAC contactors and an on-site truck loading facility.
- Ultimate disposal of the spent carbon becomes the responsibility of the contractor, thereby releasing the District from any potential future liability.
- Manpower requirements for plant maintenance are reduced.

Based on these considerations, use of a contract carbon replacement service is recommended for the District's treatment facility.

G. SUMMARY OF GAC TREATMENT RECOMMENDATIONS

The major recommendations developed in this chapter for the District's treatment facility are briefly summarized as follows:

- Centralized treatment facility located at the Quebec Street site.
- Pressurized, downflow, fixed-bed GAC contactors.
- Eighteen 10-foot diameter, prefabricated steel contactors.
- Parallel contactor operation.
- Contract carbon replacement service.

CHAPTER 5

WATER COLLECTION, PUMPING, AND DISTRIBUTION MODIFICATIONS

A. PRESENT OPERATION

The District's shallow wells at 80th Avenue and Jasmine Street, 77th Avenue and Pontiac Street, the District Office, and 64th Avenue and Quebec Street pump directly into adjacent storage reservoirs. The two wells at 77th Avenue and Quebec Street have no adjacent tank and pump through approximately 3 miles of transmission lines to the reservoirs at 64th Avenue and Quebec Street and 56th Avenue and Niagara Street.

Numerous comparative evaluations were made of alternative piping networks and plant locations in order to determine the most efficient method of providing treatment to the shallow well supplies and returning the treated water to the distribution system. These evaluations are presented below.

B. WELL SUPPLY LOCATIONS

As described in Chapter 3, shallow well supplies to be treated consist of seven wells located at five separate sites as follows:

- 77th Avenue and Pontiac Street, Wells No. 2 and No. 3.
- 77th Avenue and Quebec Street, Wells No. 5 and No. 17.
- 64th Avenue and Quebec Street, Well No. 14.
- 80th Avenue and Jasmine Street, Well No. 15.
- District Office (6595 East 70th Avenue), Well No. 16.

The first three sites have relatively high capacity wells and are extremely important to the District's supply. The last two sites have wells which are of less importance.

C. BOOSTER PUMP STATIONS

All water treated by the District must be returned to one of the following five sites for storage and pumping into the distribution system:

- 77th Avenue and Pontiac Street, 2 million gallon storage and 3.7 mgd booster capacity.
- 64th Avenue and Quebec Street, 2.3 million gallon storage and 7.4 mgd booster capacity.
- 56th Avenue and Niagara Street, one million gallon storage and 4.1 mgd booster capacity.
- 80th Avenue and Jasmine Street, 0.3 million gallon storage and 0.8 mgd booster capacity.
- District Office, 0.6 million gallon storage and 1.5 mgd booster capacity.

The first three facilities are the principal distribution points in the District and will continue to be the primary destinations for the treated well water. The last two facilities are of lesser significance in the District.

D. WATER TRANSFER MODEL

An evaluation was made to determine the economic feasibility of collecting, treating, and returning the water to all the District's facilities. The analyses indicated that the well supplies at both the District Office site and 80th Avenue and Jasmine Street site are too small to justify the costs of collection facilities to convey water from them to the site of the water treatment facility, and that the storage and booster facilities at these sites are too small to justify the cost of transmission facilities to deliver treated water to them. Decreed pumping rates from these two smaller wells can be transferred to one of the three larger sites more efficiently. Consequently, the Water Transfer Model was reduced to three sources of supply and three distribution points. Maximum day flow rates which will be collected from or delivered to each of the sites, in

order to match the 12 mgd capacity of the water treatment facility, have been determined. These facilities, their planned capacities, and comments on each are tabulated below.

1. SUPPLY POINTS.

- 77th Avenue and Pontiac Street, with a developed well supply of 3.7 mgd. The site includes Wells No. 2 and No. 3, which have decrees totaling 4.4 mgd and anticipated maximum withdrawal rates totaling 3.3 mgd.
- 77th Avenue and Quebec Street, with a developed well supply of 7.1 mgd. The site includes Wells No. 5 and No. 17, which have a decree of 5.0 mgd and anticipated maximum withdrawal rates of 6.4 mgd.
- 64th Avenue and Quebec Street, with a developed well supply of 1.2 mgd. The site includes Well No. 14 which has a decree of 1.4 mgd and an anticipated maximum withdrawal rate of 1.2 mgd.

2. DISTRIBUTION POINTS.

- 77th Avenue and Pontiac Street, with a peak delivery of 4.5 mgd from the water treatment facility.
- 64th Avenue and Quebec Street, with a peak delivery of 4.9 mgd.
- 56th Avenue and Niagara Street, with a peak delivery of 2.6 mgd.

E. ALTERNATIVE COLLECTION/TRANSMISSION SYSTEMS

Seven alternatives were developed for collecting flow from the three supply points, conveying it to one or more water treatment facility locations, and then transmitting the treated water to the three distribution points. Several options were eliminated as economically unfeasible or technically unsatisfactory, and three alternatives emerged as meriting closer evaluation.

The three alternatives described herein were evaluated to determine their technical and economical feasibilities. The basis used for evaluation of each alternative is given below:

- Flow rates were established for maximum day conditions (12 mgd) for each of the supply points and distribution points.

- The desired location of 77th Avenue and east of Quebec Street was used for the central water treatment facility, and the two decentralized facility site locations were at 77th Avenue and Pontiac Street and at 64th Avenue east of Quebec Street.

- Collection and transmission piping networks were laid out to connect the supply points and distribution points to the treatment facility.

- Each water line was sized to carry the design flows based upon a comparison of construction costs and the head loss through the line as determined by computing annual pumping costs.

- Hydraulic grade line calculations were made through the system to determine operating pressures at key points and to establish head-discharge requirements for each of the pumps.

- A detailed estimate was made of the cost to construct all of the facilities.

- An estimate was made of the annual pumping costs for each facility, based on a unit cost of $0.06 per kilowatt-hour.

- Capital costs and pumping costs were combined, by computing the present worth of 30 years of annual pumping costs at an interest rate of 8 percent.

Descriptions of the three alternatives, accompanied by schematic layouts of the piping networks and estimates of capital and operating costs of each, follow.

1. <u>PRESSURIZED SYSTEM</u>. In this alternative, flow from the three supply points is collected by water lines which join near the entrance to the treatment facility. The water passes through the GAC contactors, then is conveyed through transmission lines back to the three storage reservoirs under pressure supplied from the well pumps. Water withdrawn from any one well can be pumped to any of the distribution points with control provided by the operation of valves at each of the storage reservoirs.

The advantages of this system are simplicity and interchangeability. Each well pump provides standby supply for all other pumps, and each GAC contactor in the treatment facility is interchangeable with all the other

units. Booster pumps at the three reservoir sites also provide standby protection for each other, since any treated well supply water can be directed away from stations experiencing operating difficulties.

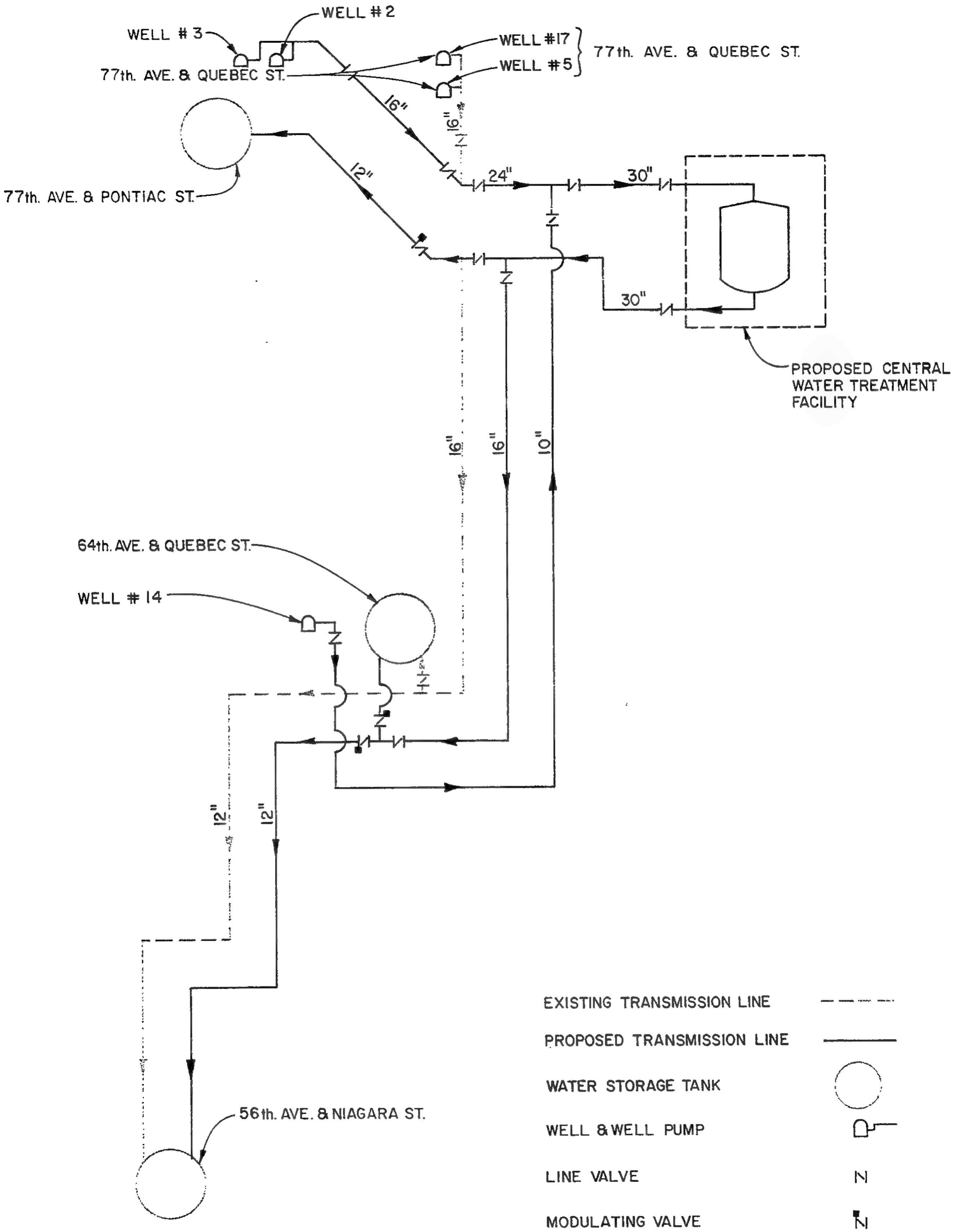
The only significant disadvantage of this alternative is that the well pumps operate at higher heads than the other alternatives. This is reflected in the somewhat higher operating costs than the other alternatives.

Figure 5-1 illustrates a schematic layout of the pressurized system alternative and indicates existing and new pipeline sizes and required interconnections. Table 5-1 presents the estimated costs.

2. CLEARWELL SYSTEM. This alternative incorporates a clearwell into the water treatment facility. As in the pressurized system alternative, flow from the three supply points is collected by water lines which join near the entrance to the treatment facility. The water passes through the treatment units under pressure supplied by the well pumps and then enters the clearwell, which is open to atmosphere. Consequently, well pumps at the supply points pump at a lower head than in the pressurized system alternative. A series of booster pumps withdraw water from the clearwell at the treatment facility and pump through transmission lines to the storage reservoirs.

This alternative has the advantage that the clearwell booster pumps required to pump water to the 77th Avenue and Pontiac Street reservoir can operate at a lower head than those pumps which transmit water to the other reservoirs. This alternative requires separate effluent lines from the treatment facility but reduces annual pumping costs.

The reduced pumping cost is offset by the capital costs of the clearwell and booster pumps. This alternative also has the disadvantages of requiring an additional pumping station in a system that already has numerous pumps, with resulting increased operational difficulties and higher maintenance costs. In addition, the lower discharge head booster pumps at the clearwell cannot provide standby service for the other pumps, since the lower head pumps cannot pump to the higher storage reservoirs.



PIPELINE SCHEMATIC
FULLY PRESSURIZED ALTERNATIVE

Figure 5-1

TABLE 5-1

ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COSTS
PRESSURIZED SYSTEM ALTERNATIVE

Description	Cost ($)
Pipelines and Appurtenances	1,226,000
Pumps	177,000
Asphalt Removal and Replacement*	66,000
TOTAL	$1,469,000
Estimated Annual Power Costs, at $0.06 per kWh	105,000
Present Worth Value of 30 Years of Pumping	1,183,000
TOTAL, Capital and Pumping Costs	$2,652,000

*Assumes lines on Quebec Street, between 77th Avenue and 58th Avenue, can be built in an easement on the east edge of Quebec on Arsenal property.

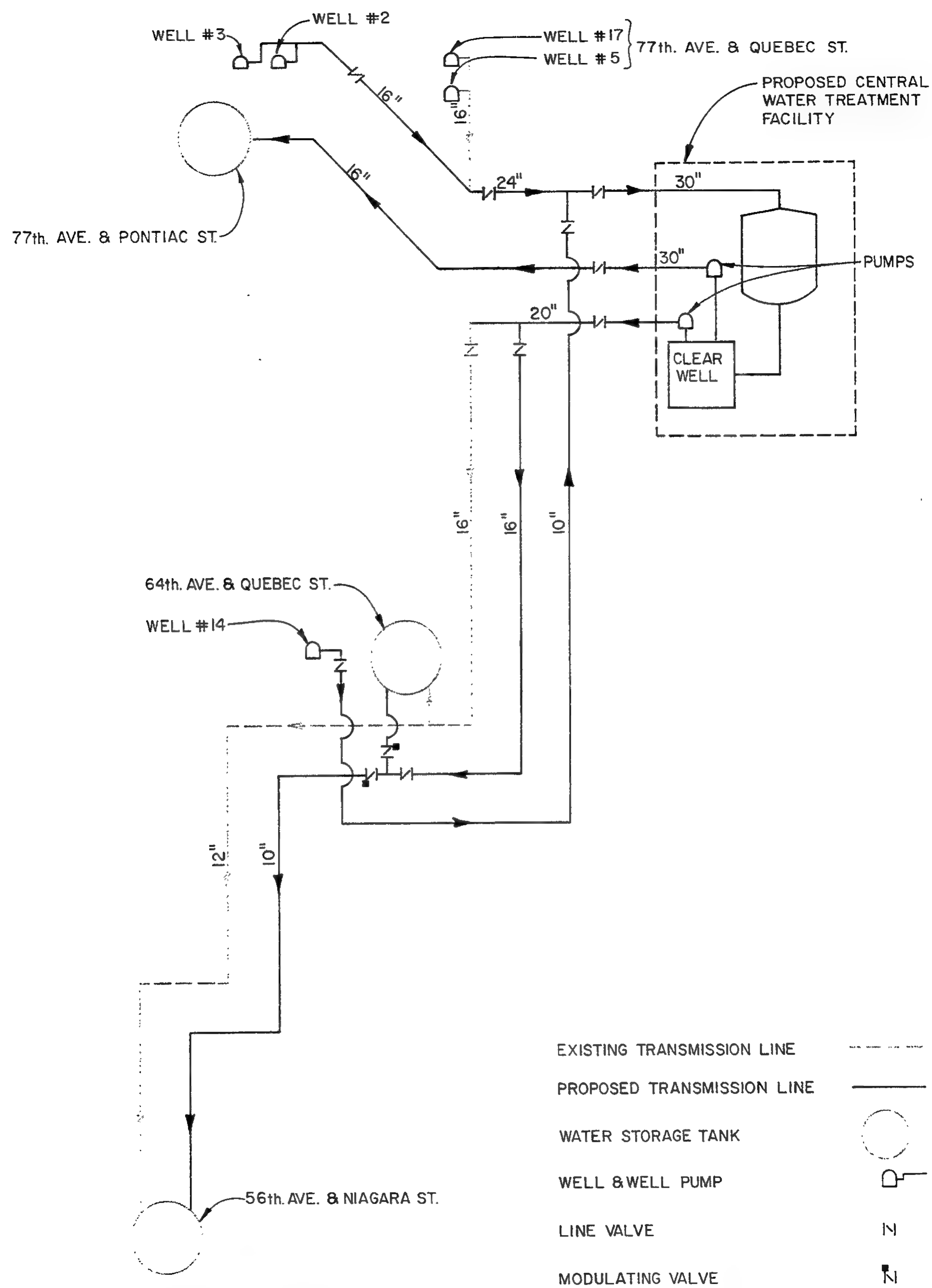
Figure 5-2 illustrates the schematic piping plan for the clearwell system alternative, including existing and new pipeline sizes and interconnection requirements. Table 5-2 presents the estimated costs.

3. DECENTRALIZED WATER TREATMENT FACILITIES. Several decentralized alternatives were considered, with the layout shown schematically on Figure 5-3 emerging as the most favorable. This alternative employs two water treatment facilities, one adjacent to the 77th Avenue and Pontiac Street site and one near the 64th Avenue and Quebec Street site. The two facilities would operate independently from each other.

The decentralized alternative has the advantage of simplicity, since it resembles the present system operation. Table 5-3 also illustrates that the capital costs for the pipeline improvements are considerably lower than those of the other alternative, primarily because new transmission pipelines between 77th Avenue and 56th Avenue are unnecessary.

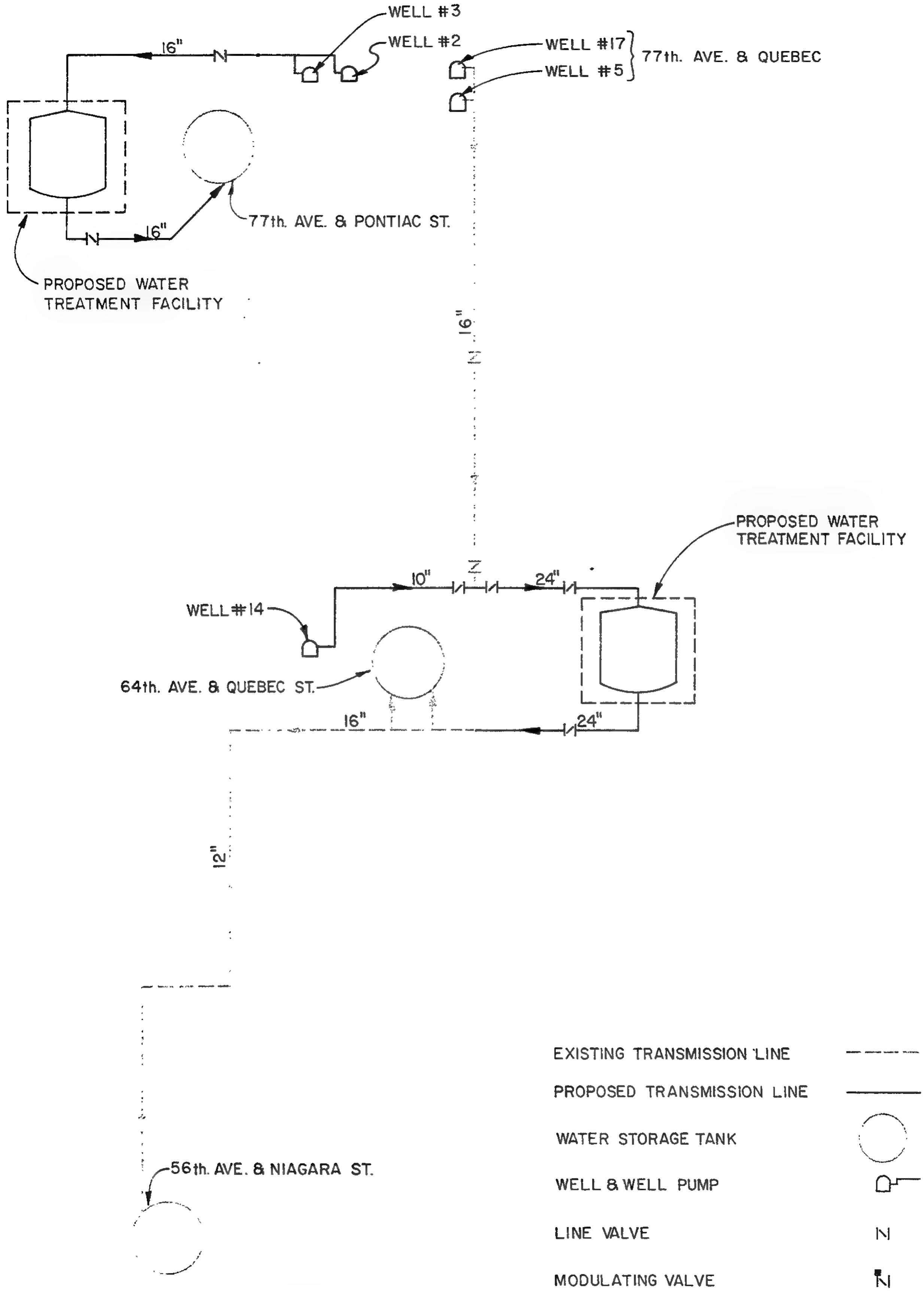
The alternative has a number of disadvantages. The use of the existing transmission lines results in higher head losses and, therefore, greater pumping costs. Because the two systems are not connected, one facility cannot provide backup for the other. While the capital cost of system piping improvements for the decentralized facilities alternative is lower than the preceding alternatives, this saving is more than offset by the increase in capital, operation, and maintenance costs of the two smaller treatment facilities over the same costs for a single central facility.

Table 5-4 presents a comparison summary of the costs for the three alternatives. The costs represent only the improvements to the well pumps, the collection and transmission systems, and the power costs required to operate these elements of the system. The costs of facilities within the water plants are not included.



PIPELINE SCHEMATIC
CLEARWELL ALTERNATIVE

Figure 5-2



PIPELINE SCHEMATIC
DECENTRALIZED PLANTS ALTERNATIVE

Figure 5-3

TABLE 5-2

ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COSTS
CLEARWELL SYSTEM ALTERNATIVE

Description	Cost ($)
Pipelines and Appurtenances	1,138,000
Pumps	126,000
Asphalt Removal and Replacement*	66,000
TOTAL	$1,330,000
Estimated Annual Power Costs, at $0.06 per kWh	92,000
Present Worth Value of 30 Years of Pumping	1,037,000
TOTAL, Capital and Pumping Costs	$2,367,000

*Assumes lines on Quebec Street, between 77th Avenue and 58th Avenue, can be built in an easement on the east edge of Quebec on Arsenal property.

TABLE 5-3

ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COSTS
DECENTRALIZED WATER TREATMENT ALTERNATIVE

Description	Cost ($)
Pipelines and Appurtenances	144,000
Pumps	209,000
TOTAL	$ 353,000
Estimated Annual Power Costs, at $0.06 per kWh	120,000
Present Worth Value of 30 Years of Pumping	1,352,000
TOTAL, Capital and Pumping Costs	$1,705,000

TABLE 5-4

SUMMARY OF COSTS OF
COLLECTION/TRANSMISSION SYSTEM ALTERNATIVES

	Capital Costs ($)	Present Worth of Pumping Costs ($)	Total Cost ($)
Pressurized System (Figure 5-1)	1,469,000	1,183,000	2,652,000
Clearwell System (Figure 5-2)	1,330,000	1,037,000	2,754,000[(1)]
Decentralized Water Treatment System (Figure 5-3)	353,000	1,352,000	1,705,000

[(1)]Total cost for this alternative includes $2,367,000 for collection/transmission modifications and $387,000 for the clearwell and pumping station at the water treatment plant.

F. RECOMMENDED ALTERNATIVE

The pressurized system depicted on Figure 5-1 is the best technical and economical alternative for the collection and transmission system, based upon the cost estimates presented in this chapter, combined with the cost estimates of the treatment facility alternatives. The system consists of the following key elements:

- New collection lines from all three supply well sites to the water treatment facility site.
- New well pumps and motors at each of the five wells at three supply sites (Wells No. 2, 3, 5, 14, and 17) to pump greater flow rates at higher heads.
- New transmission lines from the water treatment facility to the three distribution points, including new lines parallel to the existing transmission lines between 77th Avenue and 56th Avenue.
- Four remote-controlled modulating valves on the transmission lines which would control the amount of flow entering each storage reservoir.
- Telemetry and control systems which would allow operation of each of the five well pumps and each of the four modulating valves from the water treatment facility control room.
- It is recommended that the use of shallow Wells No. 15 and No. 16 be discontinued and that the smaller storage reservoirs at the 80th Avenue and Jasmine Street site and at the District Office not be connected to the transmission system. These sites would continue to be used for pumping, storage, and distribution of deep well water, and the reservoirs could be filled from the distribution system in times of off-peak usage, so that the water could be pumped back to the system during peak usage periods.

G. POWER COSTS

The power costs presented in Tables 5-1, 5-2, and 5-3 represent the total power costs to operate the entire collection and transmission systems. A portion of the operating costs could be attributed to the need to incorporate the water treatment facility into the District's operation. The remainder of the operating cost would be attributable to the normal operation of the District (at the time that the maximum daily shallow well withdrawal would reach 12 mgd) without the need to provide water treatment.

In order to provide a basis for comparison, a computation was made to the annual cost to provide the same flows to the southern portion of the District, without the need for water treatment. This annual pumping cost is estimated to be $61,000 per year and to have a present worth value of $686,000.

The value can be compared to those tabulated in Table 5-4, and the difference can be viewed as the increased cost of system operation resulting from the provision of water treatment. For example, the annual cost of operating the recommended alternative, the pressurized system, is estimated in Table 5-1 to be $105,000. Consequently, the difference of $44,000 per year, with a present worth value of $497,000, is the operating cost which will be associated with the need to provide water treatment.

CHAPTER 6

ADMINISTRATION AND SUPPORT FACILITIES

This section outlines the administration and laboratory support areas, monitoring and control systems, and other facilities necessary to support the recommended treatment alternative.

A. ADMINISTRATION AREA

A centralized treatment facility requires administrative areas be provided to support operations. Figure 6-1 indicates a layout of the building areas recommended for the facility. Identified on the figure are the different types and approximate sizes of building areas to be included at the site.

A description and justification for each of the different areas follows:

- Control Room. The control room will monitor/control treatment plant operations and the associated supply wells, water collection, and transmission system modifications.

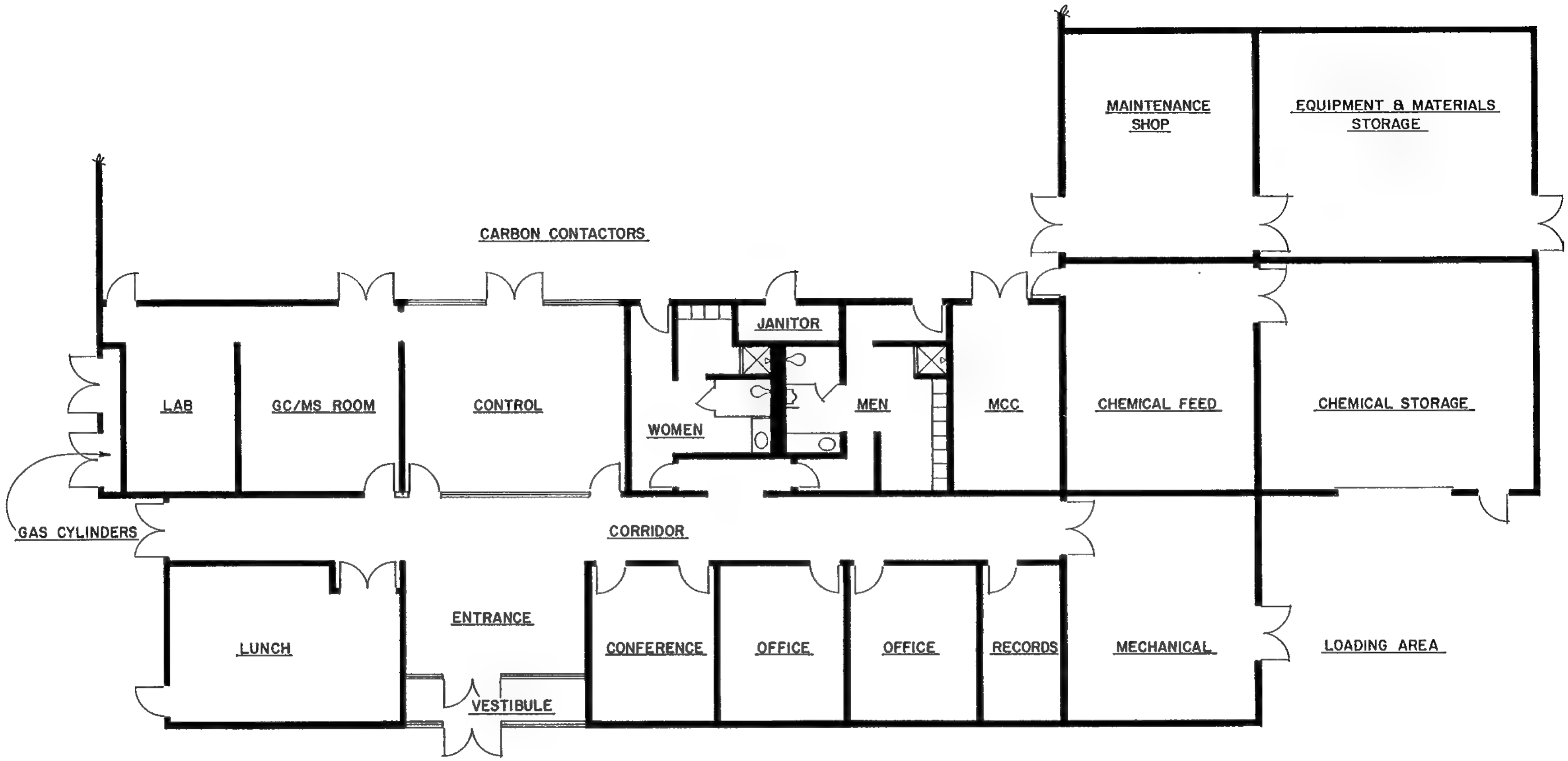
- Laboratory. A laboratory is needed to monitor traditional water quality parameters such as coliform and chlorine residual. Additionally, a section of the laboratory is dedicated to installation of a gas chromatograph/mass spectrophotometer which is necessary in order to implement the organic contaminant testing requirements discussed later in this chapter.

- Lunchroom. A lunchroom with table space, refrigerator, and sink will be provided at the treatment facility.

- Conference Room. Meetings with staff, regulatory officials, equipment suppliers, and concerned public interest groups will be held in the conference room.

- Office. An office will be needed for the District supervisor responsible for plant operations. An additional office is needed for shared use between the plant operator and chemist.

- Record Storage.. Operating records and data, plant maintenance files, equipment catalogs, O&M manuals, and office supplies will be located at the record storage area.



ADMINISTRATION AREA

Figure 6-1

- Maintenance Shop. Work benches, minor repair equipment, control and instrumentation repair, and associated shop maintenance work will be performed at this location.

- Mechanical Room. This room will enclose the facility's mechanical systems, including air handling equipment, compressed air system, water heater, and plant heating.

- Locker Room. Men's and women's locker and restroom facilities will be provided at the treatment facility.

- Chemical Feed and Storage. Disinfection facilities will include chemical feed equipment for chlorine, ammonia, and possibly sodium hydroxide. Chemical storage will include chlorine cylinders and bulk liquid ammonia vessels.

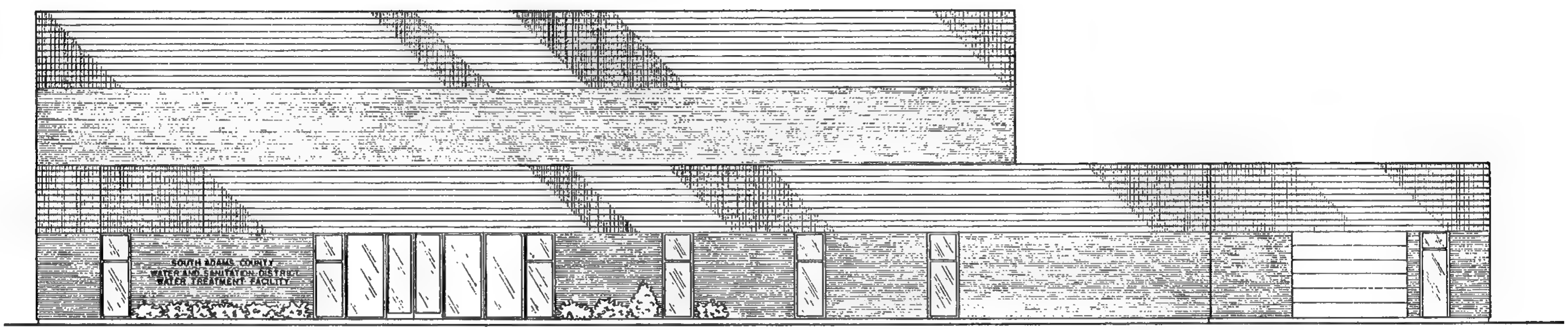
The total administrative area needed is estimated to be approximately 6,700 square feet. The chemical feed and storage areas, mechanical room, maintenance shop, and material storage spaces are estimated to contribute approximately 2,200 square feet to the total administrative area.

The building architecture is to be aesthetically pleasing and a good neighbor to the adjacent community. Figure 6-2 is intended to illustrate the general appearance of the type of facility desired. Three alternative wall materials are available which can meet the serviceability and aesthetic impact criteria of the project. The materials and the considerations evaluated are as follows:

- Textured precast concrete panels provide a low maintenance, durable, and attractive building finish. This type of construction has a fast construction schedule.

- Brick masonry walls provide a low maintenance, durable, and attractive building finish. Brick construction requires a longer period than precast concrete panels to erect.

- Precast concrete panels or brick masonry in combination with prefabricated curtain wall panels may provide the most attractive architectural treatment for a facility the size of the District's plant.



WATER TREATMENT FACILITY ELEVATION

Figure 6-2

All three alternative materials result in approximately the same capital cost for the treatment building. The desired architectural treatment and type of building materials will be selected during the design phase of the project.

B. ANALYTICAL LABORATORY EQUIPMENT

This section discusses the rationale for the recommendation to provide GC/MS analytical testing capability at the treatment facility.

As previously discussed in Chapter 5, the GAC contactors will be operated in a parallel configuration. Startup of the units will be staged such that breakthrough and exhaustion of the beds occurs sequentially. This mode of operation will allow effluent from both fresh and partially-exhausted beds to be blended to achieve the desired final effluent quality. However, plant operators must be able to closely monitor the TCE concentration in each contactor's effluent in order for parallel operation to achieve maximum utilization of the carbon's adsorptive capacity and, thereby, extend the carbon bed life and reduce operating costs.

Three alternative methods of water quality testing to monitor plant performance and control operations were evaluated, and a present worth cost comparison is indicated in Table 6-1. The alternatives are described as follows:

- Alternative A. GAC contactors are operated until initial breakthrough of the contaminant is detected (approximately one ug/l TCE in contactor effluent). Once breakthrough occurs, the GAC unit is taken out of service and the carbon regenerated. Obviously, this method of operation results in the highest possible carbon usage rates. For this alternative, it is assumed that breakthrough occurs about every 12 months (a GAC usage rate of about 0.1 pound per 1,000 gallons of water treated) and that all analytical testing is contracted from an outside laboratory. The minimal testing requirements needed to assume reliable operations under this scenario consist of sampling each GAC contactor effluent line, plant influent and effluent lines, and the supply wells about every two weeks. This results in approximately 528 analyses each year assuming no plant upsets or duplicate samples due to questionable data. The present worth cost of this alternative is approximately $4,281,000. It should be noted that much more frequent testing would be required if TCE contamination

TABLE 6-1

PRESENT WORTH ANALYSIS OF ANALYTICAL TESTING ALTERNATIVES[1]

	Annual Costs ($)
Alternative A - GAC Contactor Operated Only to Breakthrough	
Carbon Replacement	320,000
Analytical Testing[2]	58,080
Sampling and Data Evaluation (10 hours/month)	2,160
Total Annual Costs	380,240
Present Worth	4,281,000
Alternative B - GAC Contactor Operated Beyond Breakthrough	
Carbon Replacement	256,000
Analytical Testing[2]	113,520
Sampling and Data Evaluation (20 hours/month)	4,320
Total Annual Costs	373,840
Present Worth	4,209,000
Alternative C - GAC Contactor Operated Beyond Breakthrough	
Carbon Replacement	256,000
Unlimited Analytical Testing	0
Sampling, Laboratory Analysis, Data Evaluation (80 hours/month)	17,280
GC/MS Service Contract	25,000
Total Annual Costs	298,280
Present Worth	3,358,000
Initial Capital Cost for GC/MS	235,000
Total Present Worth	3,593,000

(1) Present worth analysis is based on an interest rate of 8 percent and a design life of 30 years.

(2) Based on estimated contract laboratory price of $110 per sample for VOC GC analysis.

levels increase or significant concentrations of additional types of organic pollutants appear in the ground water supplies. These changes would greatly increase the cost of this alternative.

- Alternative B. GAC contactors are operated to achieve maximum carbon usage (0.08 pounds per 1,000 treated gallons), thereby requiring close monitoring of each contactor's effluent quality. This method assumes that the individual GAC units could be operated until effluent TCE concentrations are at least 10 ug/l. This results in extending the carbon bed life 25 percent beyond the time corresponding to initial breakthrough. Thus, it is anticipated that a carbon life of 15 months could be achieved through close monitoring and blending of the combined plant effluent. For this alternative, analytical testing is to be performed by an outside laboratory. The minimal testing requirements necessary to achieve reliable operations include sampling 10 GAC units every two weeks (no breakthrough detected in these units), sampling twice each week the blended plant effluent and six GAC contactors where partial breakthrough is occurring, and testing the plant influent and supply wells twice each month. This monitoring program requires about 1,032 analyses to be performed each year (again assuming no operational problems). The present worth cost of this alternative is $4,209,000.

- Alternative C. GAC contactors are operated to achieve maximum carbon usage (0.08 pounds per 1,000 treated gallons) similar to Alternative B. A GC/MS is utilized on-site to perform all laboratory analyses. District personnel operate the equipment, and it is assumed that 20 hours per week would be spent on water quality testing. The present worth value of this alternative is $3,593,000.

The present worth analysis of the different methods for monitoring plant performance and controlling treatment operations indicates that on-site GC/MS analytical testing is the preferred alternative. There are additional cost savings and operational advantages associated with on-site laboratory analyses. These benefits include:

- The ability to immediately determine laboratory results and, consequently, more closely control treatment operations.

- Verify data accuracy and variability by performing multiple analyses.

- Monitor the GAC units to determine the effects of operationing conditions on initial startup, backwashing, and carbon bed disinfection practices.

- Optimize the performance of the GAC units through an evaluation of process parameters such as hydraulic loading rates and activated carbon physical properties.

- Additional testing and monitoring of well field contamination in order to further identify pollutants, areas of highest contamination and temporal variability.

A GC/MS analytical instrument is recommended for the laboratory rather than just a gas chromatograph since in addition to VOCs other synthetic organics and pesticides are also present in the ground water. These other chemicals require GC/MS analytical techniques for detection and measurement. The non-volatile chemicals most commonly detected consist of diisopropylmethyphosphosponate (DIMP), dicyclopentadiene (DCPD), and chlorinated pesticides. Although the current concentration levels for synthetic organics are very low, monitoring is required to meet drinking water standards. The District also routinely tests both supply and sampling wells as a part of a continuing ground water monitoring program, and a GC/MS could be used to analyze these samples. Additionally, if concentrations of synthetic organics increased in the future, then these compounds would probably become the controlling parameters for operation of the treatment facility since these chemicals are less adsorbable than TCE. Analytical testing at the plant would shift from monitoring the GAC units for TCE breakthrough (gas chromatography) to analyzing for synthetic organics (GC/MS).

In summary, a GC/MS laboratory instrument is recommended in order to provide the District with the analytical capability necessary to efficiently and cost effectively monitor and control GAC treatment operations. This will allow the District to maintain close control of the effluent quality of the individual GAC units and will ensure maximum use of the activated carbon's adsorptive capacity. A GC/MS will allow the District to evaluate the contamination levels for all types of hazardous compounds known to be present in the existing ground water supply.

C. WATER TREATMENT CONTROL SYSTEM

The water delivery, storage systems, and treatment plant operations will require close monitoring. The plant operator will have access to realtime system data through an operator control console located in the plant control room. The operator's console will be part of an overall supervisory control system which will be designed to monitor all plant control functions, including influent flow, backwash flow, and equipment alarms. GAC contactor operation and backwash control will also be included in the instrumentation system to optimize plant operations and reduce operating costs.

Existing storage reservoir and well sites will be monitored at the water treatment plant control room using the supervisory control system. At present, the existing wells discharge directly to the respective reservoir and local controls start and stop the well pumps based on the reservoir level. The water collection and transmission modifications will direct well discharge to the water treatment plant before going to the reservoirs. These hydraulic system changes will require well controls to be changed so that the wells can be operated from a central location, i.e., the water treatment plant. Critical well and reservoir parameters will be monitored and malfunctions will be alarmed. Electrical modifications at the wells include replacement of motor starting equipment to accommodate larger motors and the addition of field sensing equipment to provide remote monitoring and control.

CHAPTER 7

DESCRIPTION OF RECOMMENDED PLAN

As determined in Chapters 4 and 5, pressurized downflow GAC contactors and pressurized water collection and transmission system modifications are the recommended alternatives for accomplishing organic contaminant removal.

A. RECOMMENDED FACILITIES

1. WATER SYSTEM MODIFICATIONS. The water collection and transmission system modifications required to integrate the treatment facilities into the District's existing system are shown on Figure 7-1.

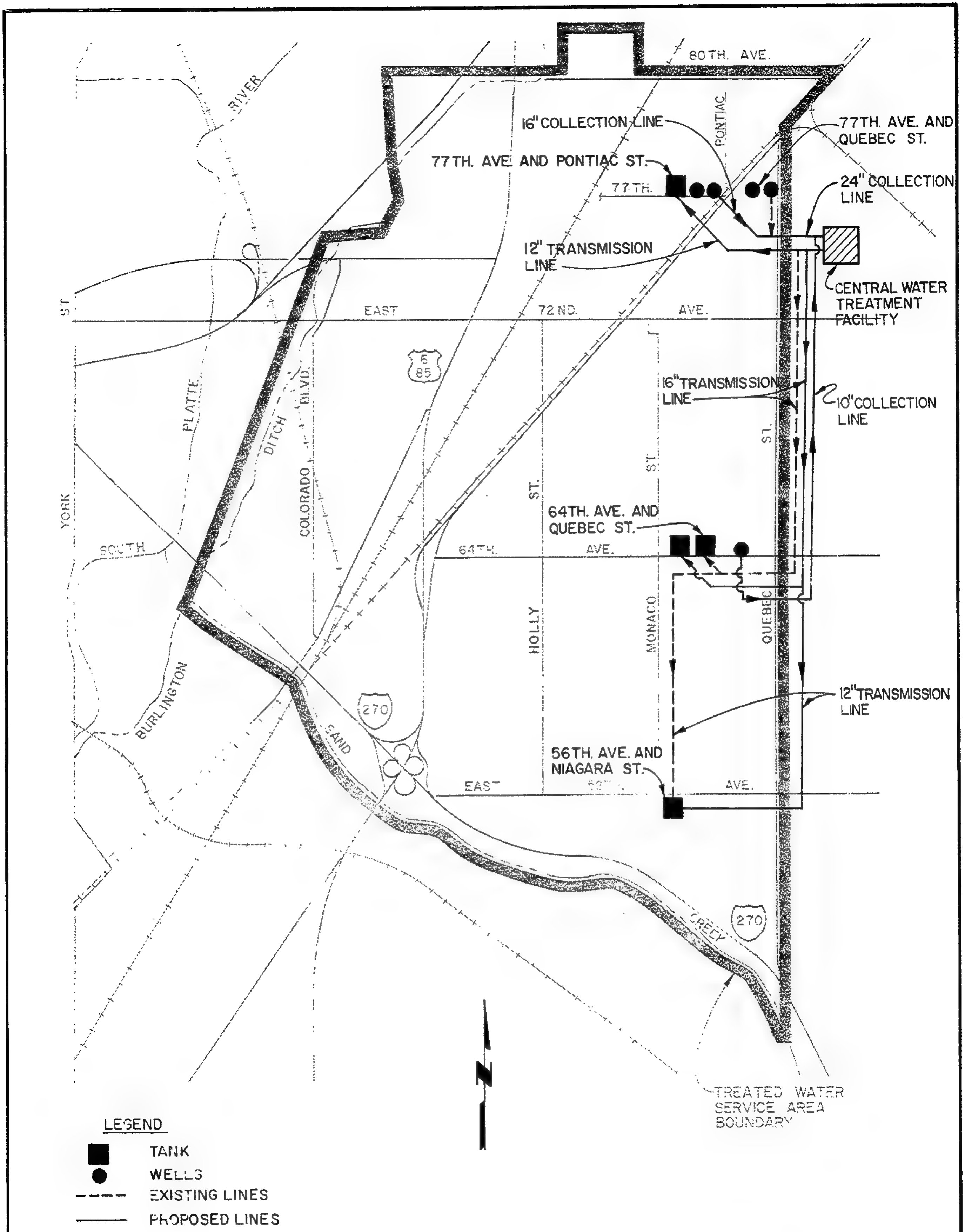
The northern service area boundary for this study has been set at 80th Avenue. Supply wells, collection, and transmission piping north of 80th Avenue are not a part of the recommended improvements addressed herein.

a. Well Supply. Of the seven District well supplies located at the five separate sites inside the service area boundary, only the five most productive wells are incorporated in the proposed system improvements. These wells include the two wells (Wells No. 2 and No. 3) at 77th Avenue and Pontiac Street, the two wells (Wells No. 5 and No. 17) at 77th Avenue and Quebec Street, and Well No. 14 at 64th Avenue and Quebec Street. The use of shallow wells at 80th Avenue and Jasmine Street (Well No. 15) and at the District's office (Well No. 16) should be discontinued and their decrees should be transferred to the other wells.

The capacities of these five shallow wells will be increased to provide a total supply of 12 mgd. The shallow well sites and modified flow requirements are shown in Table 7-1.

No modifications are recommended for the District's existing deep wells. They should continue to pump directly into the storage reservoirs adjacent to each well site.

b. Collection and Transmission Pipelines. Modifications to the collection and transmission pipelines as shown on Figure 7-1 will permit water supplies from the five wells at the three separate site locations



RECOMMENDED WATER SYSTEM FACILITIES **Figure 7-1**

TABLE 7-1

WATER SYSTEM MODIFICATIONS
DESIGN CRITERIA

Location	Well No.	Present Capacity (mgd)	Required Capacity (mgd)
77th Avenue and Pontiac Street	2 & 3	2.6	3.7
77th Avenue and Quebec Street	5 & 17	3.6	7.1
64th Avenue and Quebec Street	14	1.2	1.2
Total		7.4	12.0

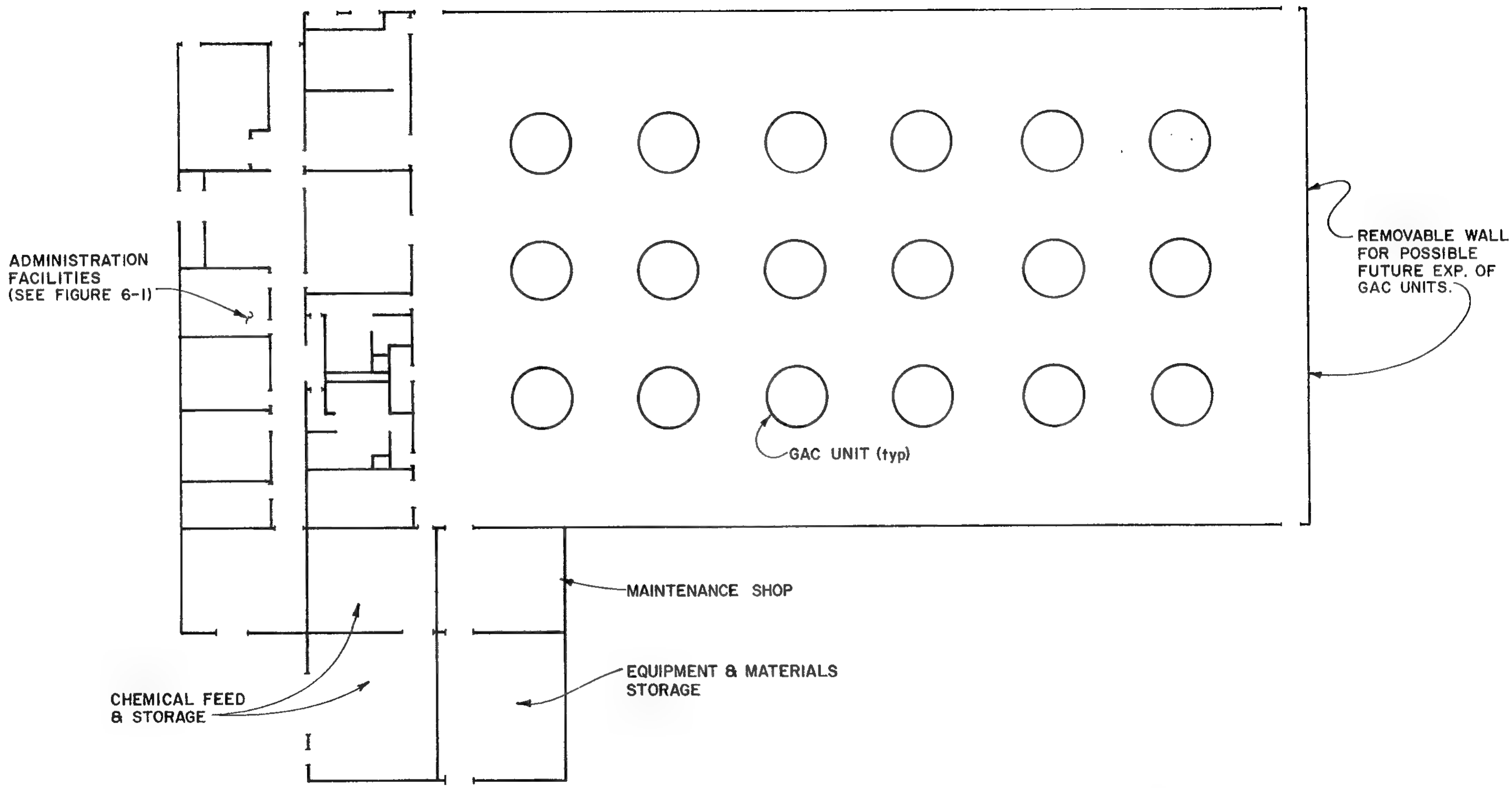
inside the service area boundary to be collected, conveyed to the treatment facility, and then transmitted back to the existing storage reservoirs. New water lines parallel to existing water lines are necessary at locations which require greater flow capacity than the existing lines can provide.

c. Storage Reservoirs. Effluent from the treatment facililty will be conveyed to only three of the District's five storage reservoir locations inside the service area boundary. The three site locations are 77th Avenue and Pontiac Street, 64th Avenue and Quebec Street, and 56th Avenue and Niagara Street. The other sites will be used only in conjunction with deep well supplies. Shallow well supply connections to these other reservoirs will be removed.

2. GAC TREATMENT FACILITY. The layout of the GAC contactors, administration building, and support areas is shown on Figure 7-2. The facility will be located east of Quebec Street at 77th Avenue on Rocky Mountain Arsenal property and have a maximum day treatment capacity of approximately 12 mgd.

The treatment process consists of 16 downflow, fixed-bed GAC pressure contactors. Two additional GAC units provide reserve capacity and reserve carbon storage. The treatment process includes provisions for backwashing, new and used carbon transfer, and chemical addition. Chlorine, chloramines, and possibly sodium hydroxide will be capable of being added to the flow either before or after carbon adsorption. Chemical addition will also be possible during backwash operations. Table 7-2 indicates the GAC contactor design parameters.

The carbon usage rate at breakthrough is estimated to be approximately 0.08 pounds per 1,000 gallons of treated water for the existing contaminant concentrations measured in the well supply. This usage rate corresponds to a carbon bed life of approximately 15 months. The District will utilize a commercial carbon replacement service for removal of exhausted carbon and replacement with fresh carbon. Regeneration or approved disposal of the spent carbon will be the responsbility of the contract service.



WATER TREATMENT FACILITY LAYOUT

Figure 7-2

TABLE 7-2

GAC CONTACTOR DESIGN

Item	Value
Pressure Contactors	
12 mgd Treatment Capacity	16
Reserve Capacity	2
Vessel Pressure Rating, psi	100
Diameter, ft	10
Height, ft	
Carbon Bed Depth	9
Minimum Sidewall Depth	12
Loading Rate, gpm/ft^2	
Average Day	3.8
Maximum Day	6.6
Maximum Backwash Loading Rate, gpm/ft^2	25
Empty Bed Contact Time, minutes	
Average Day	18
Maximum Day	10
Carbon Use Rate[(1)], lbs/1,000 gallons	0.08

[(1)]Use rate based upon existing well supply contamination levels and utilization of Calgon F300 carbon.

The GAC contactors will be operated in parallel, and startup of the beds will be staggered such that exhaustion occurs sequentially. Effluent from both fresh and partially exhausted beds will be blended to achieve the desired final effluent quality meeting drinking water standards.

B. PRELIMINARY OPINION OF COSTS

An estimate of the capital costs for the recommended water collection and transmission system modifications and treatment facilities is presented in Table 7-3. The costs indicated in the estimate are based on a September 1986 Engineering News Record/Building Construction Cost Index (ENR/BCI) of 2504.

An estimate of the annual operating and maintenance costs associated with the treatment facility are presented in Table 7-4. The costs indicated in the table are only those attributable to implementation of the recommended plan.

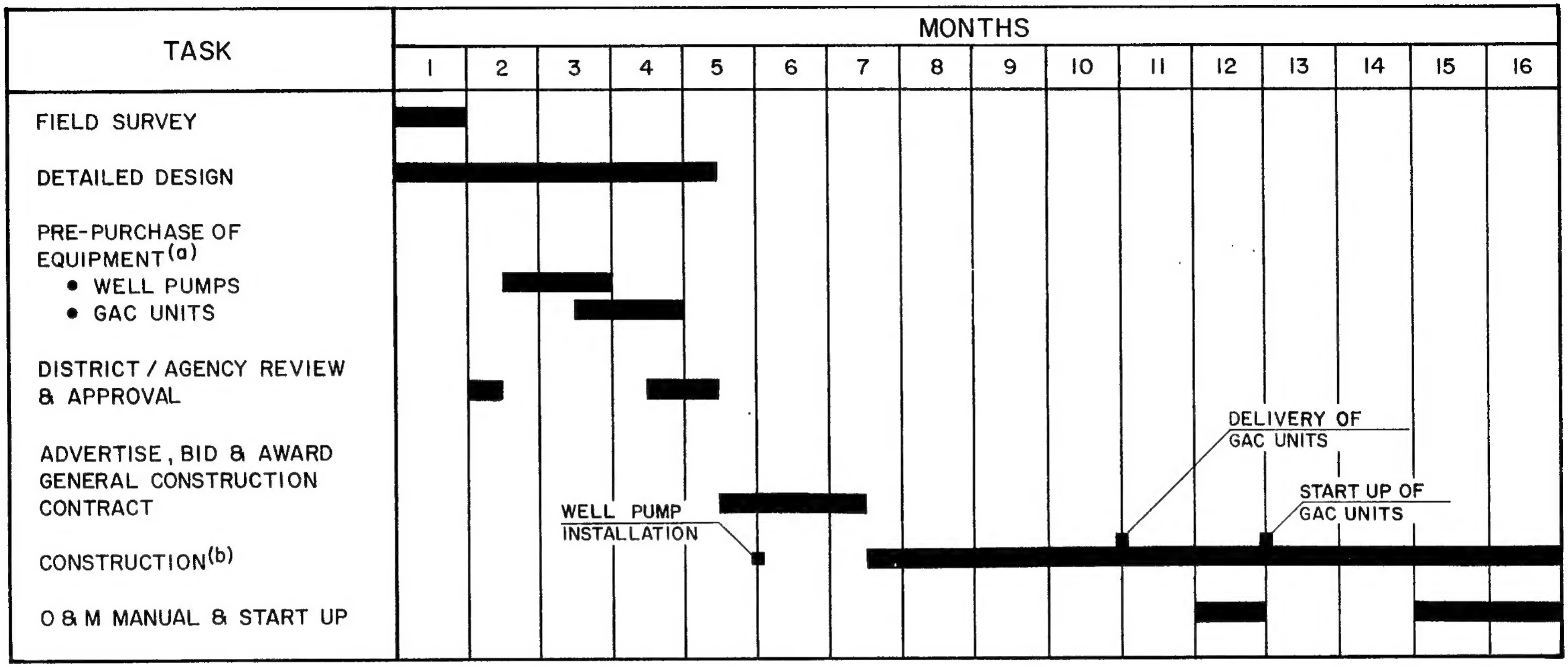
C. IMPLEMENTATION SCHEDULE

Figure 7-3 presents a schedule for implementing the design and construction of the recommended facilities.

The schedule is based on prepurchase of two items of equipment:

- The well pumping units for Wells No. 2 and No. 3 at 77th Avenue and Pontiac Street.
- The granular activated carbon (GAC) treatment units.

Early purchase and installation of two (Wells No. 2 and No. 3) of the five new pumping units is required to avoid an inadequacy of well supply during the summer 1987 high water demand period. This inadequacy is the result of the increased head loss in the collection/transmission system due to the operation of the temporary GAC treatment system; the recent addition of approximately 180 new taps to the system as the result of converting from private wells; and to offset the reduced well supply by terminating use of Wells No. 14 and No. 15.



(a) **EQUIPMENT FOR PRE-PURCHASE INCLUDES** WELL PUMPS NO. 2 & NO. 3 AT 77 TH. & PONTIAC & GAC TREATMENT UNITS. TASK INCLUDES ADVERTISEMENT & AWARD OF CONTRACT FOR PURCHASE.

(b) CONSTRUCTION SCHEDULE REQUIRES EARLY INSTALLATION OF WELL PUMPS NO. 2 & NO.3 & EARLY START UP OF THE GAC TREATMENT UNITS. FINAL COMPLETION OF ALL THE WORK IS ANTICIPATED TO BE 9 1/2 MONTHS FOLLOWING CONSTRUCTION CONTRACT AWARD.

IMPLEMENTATION SCHEDULE

Figure 7-3

TABLE 7-3

CAPITAL COSTS

	Cost ($)
Water Transmission and Colleciton Syatem	
Transmission Pipelines and Appurtenances	$ 1,226,000
Well Pumps	177,000
Asphalt Removal and Replacement	66,000
TOTAL	$ 1,469,000
Treatment Facility	
18 GAC Pressure Vessels and Piping	$ 2,592,000
Backwash Piping and Holding Tank	120,000
Initial Carbon Loading	360,000
Building for GAC Units	1,360,000
Chemical Storage and Maintenance Building	175,000
Chlorine, Ammonia, and Chemical Feed Equipment	155,000
Electrical and Instrumentation	485,000
Administration and Laboratory Building	390,000
GC/MS Laboratory Equipment	235,000
Site Acquisition[1]	0
Site Improvements	285,000
TOTAL	$ 6,157,000
Capital Cost of Recommended Facilities	$ 7,626,000
Design Engineering (8%)	610,000
Construction Engineering (5%)	381,000
TOTAL COST	$ 8,617,000

[1] This recommended plan would request the Army provide 10 acres of land for the treatment facility. This item may be increased in the future if a minimal cost, long-term lease cannot be arranged.

TABLE 7-4

ANNUAL OPERATING AND MAINTENANCE COSTS

	Cost ($)
Labor	
Operations (full-time)	58,400
Maintenance (full-time)	36,900
Laboratory (part-time)	17,500
Power[1]	
Wells[2]	44,000
Treatment Plant	54,000
Carbon Replacement[3]	256,000
GS/MS Analytical Instrument Service Contract[4]	25,000
GAC Contactor Maintenance	
Carbon Replacement Vessel Inspection	19,200
Lining Replacement[4]	25,000
Chemical Disinfection[5]	10,000
TOTAL ANNUAL O&M COSTS	$ 546,000

[1] Annual O&M costs are based on a power cost of $0.06/kWh.

[2] Power costs for the wells reflect only the additional pumping costs due to increased system pressure for recommended plan.

[3] Carbon replacement is based on a use rate of 0.08 lb/1,000 gallons and a 1.00 per pound replacement carbon cost.

[4] A GC/MS service contract would provide all maintenance and repair work required on the instrument.

[5] The lining replacement cost is based on a 10-year life and reflects an equivalent annual replacement cost.

[6] Only ammonia is included.

Early purchase of the GAC treatment units allow for early delivery and installation of these units thereby reducing the time the existing temporary GAC units remain in operation.

Assuming that a notice to proceed with design is given on or before December 1, 1986, the new GAC treatment units could be in service in early December 1987, and the water collection, pumping, distribution, and treatment facilities completed in early April 1988.